



VirginiaTech

Institute for Critical Technology and Applied Science

Ted and Karyn

Hume Center for National Security and Technology

Phase 4B / GEO EMCOMM Preliminary Design Review

Dr. Jonathan Black

Associate Professor, Aerospace and Ocean Engineering

Director, Aerospace Systems Lab, Hume Center

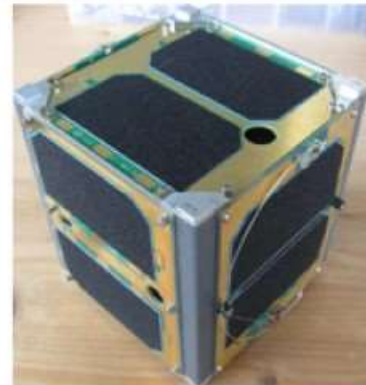
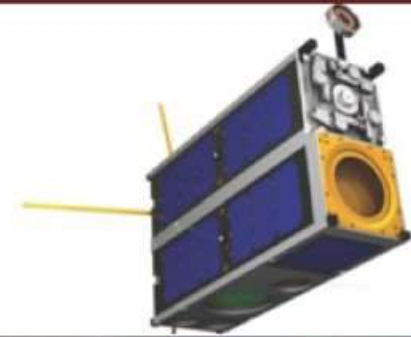
6/17/2016

hume@vt.edu
www.hume.vt.edu

Joint Cubesat Projects w/ Space@VT

All Cubesats selected for NASA ELaNa launch

1. Lower Atmosphere/Ionosphere Coupling Experiment (LAICE)
 - Developing sensors which hope to reveal new information about the neutral ion coupling processes in the 150 to 325 kilometer atmospheric region. (VT PI: Dr. Greg Earle)
 - Launch: Late 2016, Planned
2. AMSAT FOX-1A (AO-85)
 - Primarily FM Voice Transponder for Amateur Radio. VT developed a 640x480 pixel jpeg camera payload for delivering images of earth from orbit over the high speed downlink. (VT PI: Dr. Robert McGwier)
 - Launch: 8 Oct. 2015 (ELaNa XII on NROL-55)
 - <http://www.amsat.org/amsat-new/tools/predict/satloc.php?lang=en&satellite=AO-85>
3. DUSound and Temperature Imager Experiment (DUSTIE)
 - Determine the global distribution of cosmic “smoke” in the atmosphere. (VT PI: Dr. Scott Bailey)
 - Launch: TBD
4. QB50
 - The Virginia Tech Ground Station supports the QB50 project by providing ground station services.





Thank you for your support!

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www.hume.vt.edu/research/aero

www.space.vt.edu

www.aoe.vt.edu





GEO EMCOMM Payload Preliminary Design Review

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- Introductions, Mission Overview & Motivation
- Mechanical Design
- Thermal Design
- Power Supply Design
- RF Design
- AstroSDR Review
- Reset Receiver Design
- Communications Software Architecture
- Antenna Design & Link Budget Analysis

- Hands on, Minds on; RF and Security Research at Virginia Tech:
 - On-orbit learning laboratory to develop new capabilities in satellite communications and amateur radio
 - Digital protocols to enable push-to-talk, wifi, streaming video, etc.
 - Onboard processing - geolocation, co-channel, machine learning
 - App development and real time experimentation
 - Beam steering and coordinated collection
 - User authentication and prioritization
 - Open cryptography
- Program Reach:
 - Free and open access to the repeater to amateur radio operators worldwide.
 - Deployable Ground Stations to provide coverage (wifi hotspots and push-to-talk) through the GEO asset
 - Students from across Virginia Tech engaged in payload design and development, and amateur radio operations through the Virginia Tech Ground Station

- AMSAT Phase4B Project Program Specifications:

- SDR-based 5 & 10 GHz amateur satellite payload being designed to take advantage of a geosynchronous launch opportunity

- Rideshare opportunity on REDACTED

REDACTED

- Software-defined radio (SDR) payload from Rincon Research Corporation

- Program Partners:

- FEMA
- AMSAT
- ARRL
- Rincon Research Corporation

REDACTED

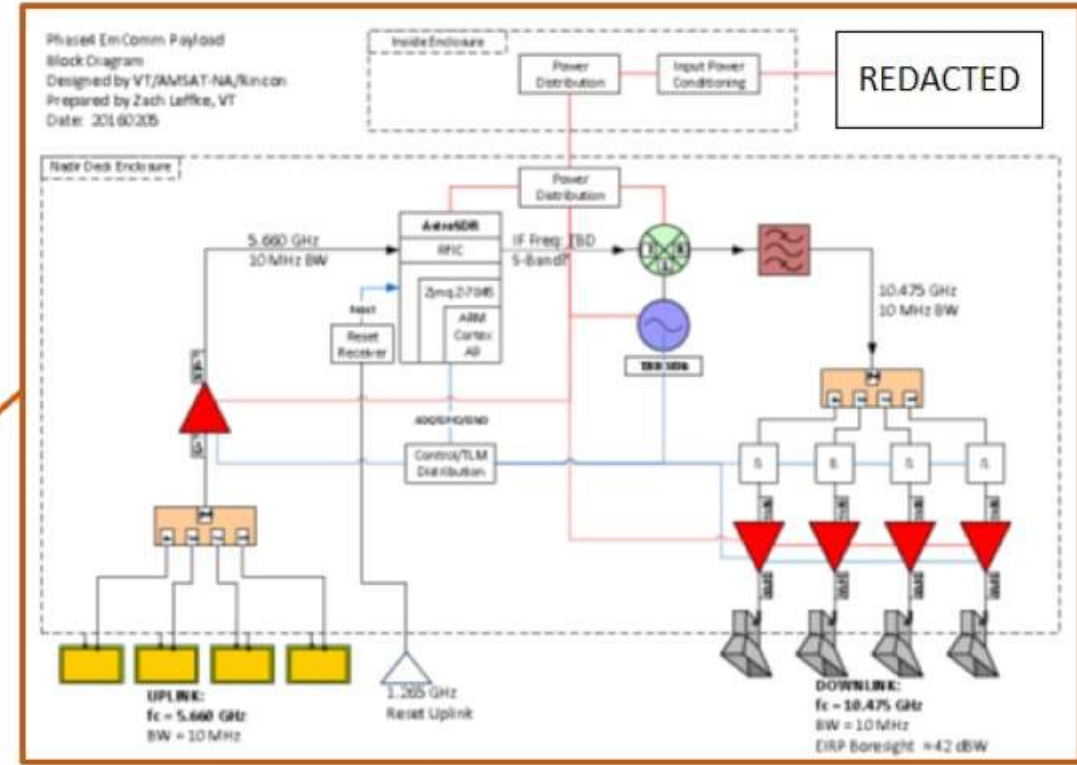
- Virginia Tech

- Hume Center
- Space@VT
- Electrical and Computer Engineering
- Mechanical Engineering
- Aerospace and Ocean Engineering

- [FEMA Blog](#)
 - <https://www.fema.gov/blog/2016-03-07/supporting-disaster-communications-space>
- [VT News](#)
 - <http://www.vtnews.vt.edu/articles/2015/12/122215-ictas-humegeoradio.html>
- [ARRL](#)
 - <http://www.arrl.org/amateur-radio-emergency-communication>

- Spring Semester 2016
 - Project Kickoff – 15 Jan 2016
 - Preliminary Interface Control Document delivered (MSS to AMSAT/VT) – 19 Feb 2016
 - Payload Flight Radio CDR – 29 Feb 2016
 - Payload PDR – 27 May 2016
 - Payload Accommodation PDR – TBD
- Summer 2016
 - Payload CDR – 5 Aug 2016
- Fall 2016
 - Engineering Model (EM) Payload delivery – 2 Sept 2016
 - EM Payload Testing complete – 16 Sept 2016
 - Payload Test Readiness Review – 4 Nov 2016
 - Payload Integration Readiness Review – 20 Dec 2016
 - Payload Delivery and Integration start – 2 Jan 2017

Virginia Tech

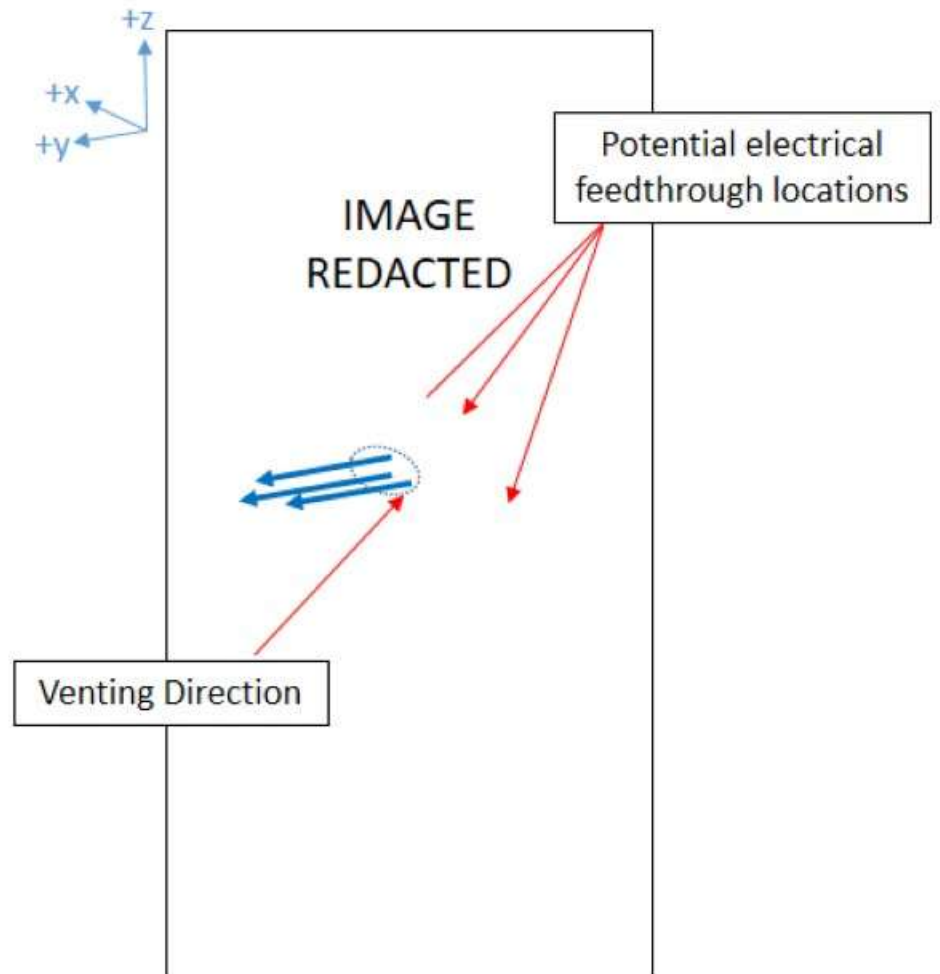
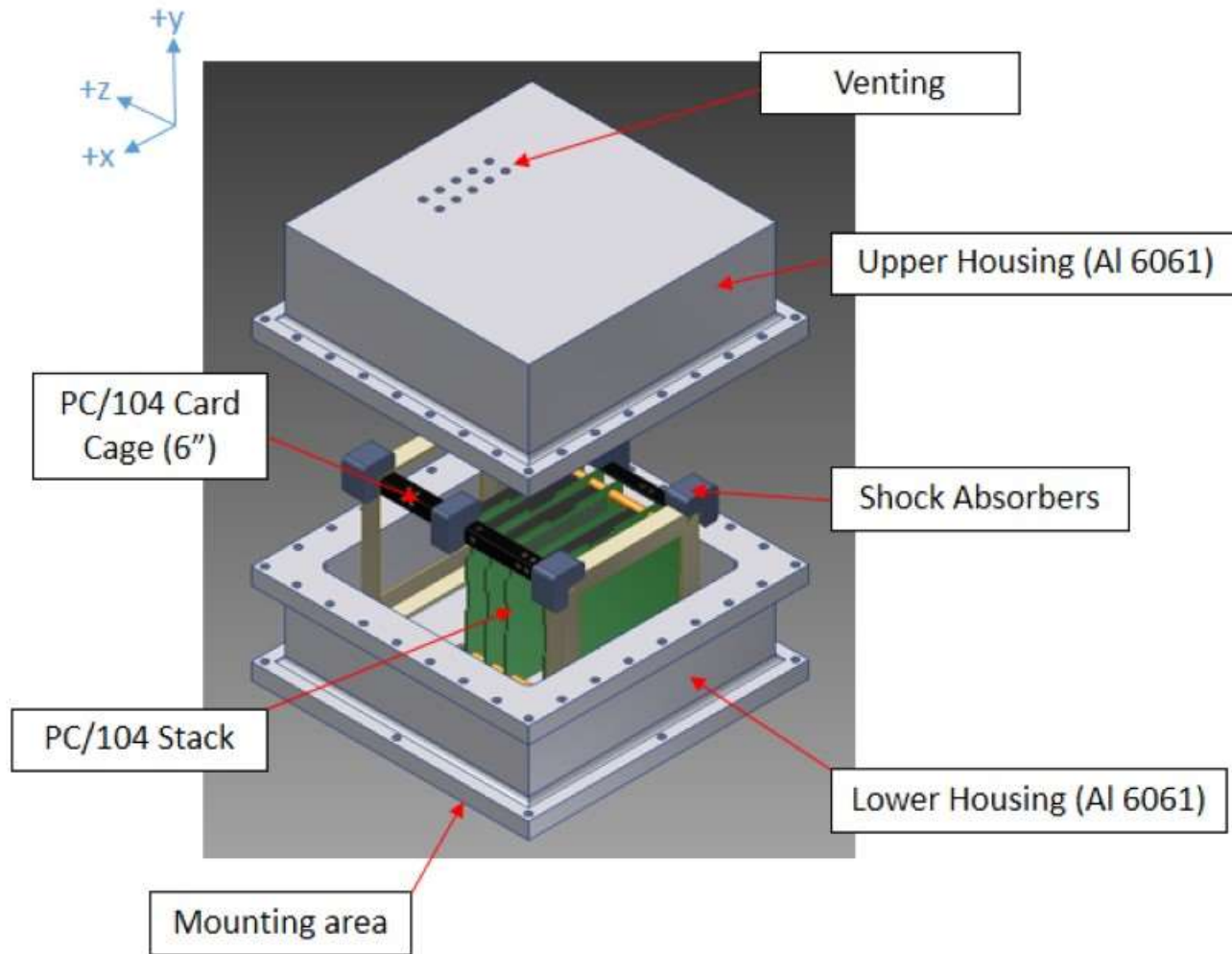


- Introductions, Mission Overview & Motivation
- **Mechanical Design**
- Thermal Design
- Power Supply Design
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- Communications Software Architecture
- Antenna Design & Link Budget Analysis

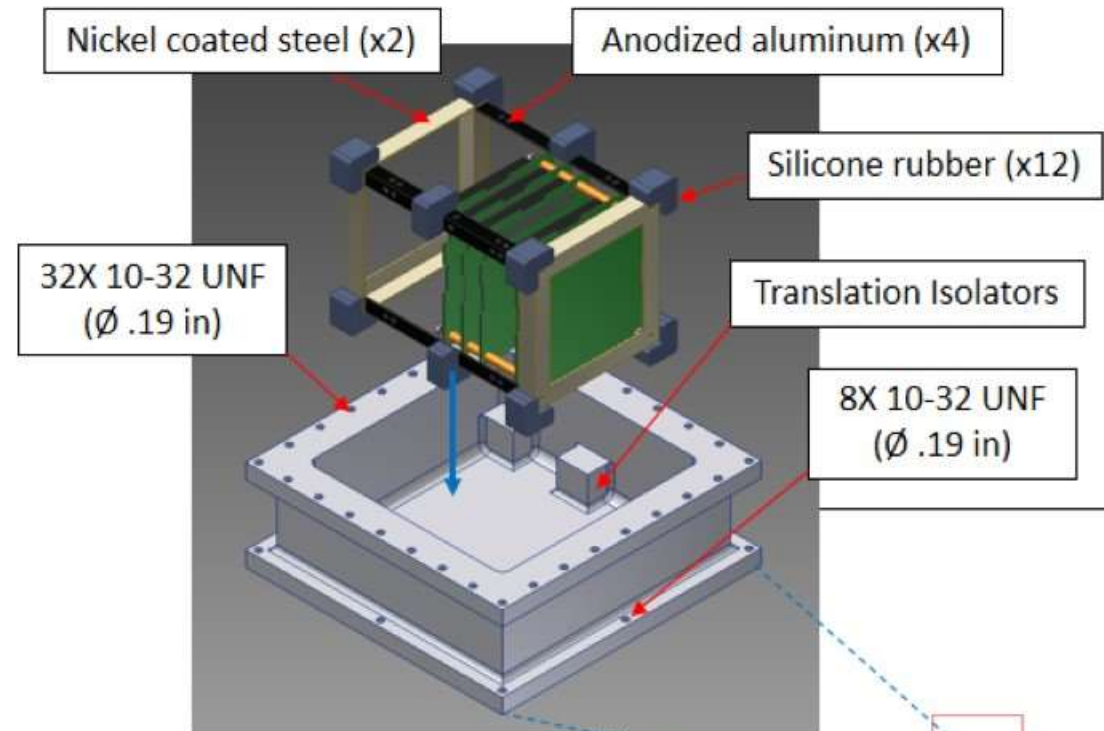
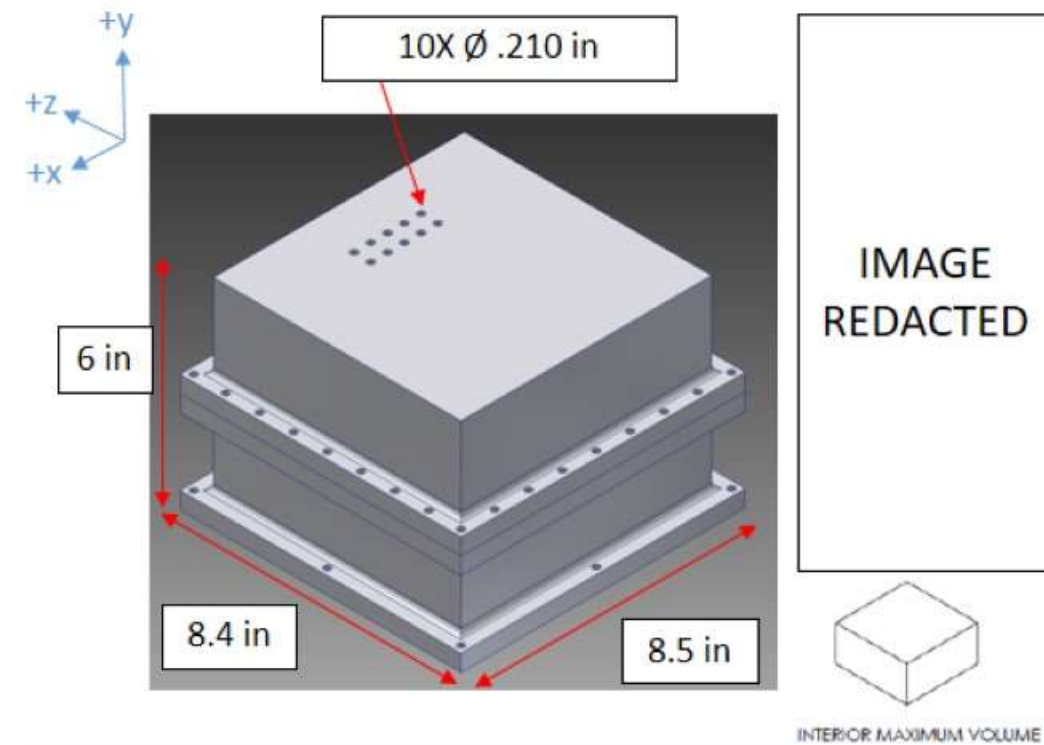
- High level overview
 - Nadir Deck Enclosure– communication processing
 - Internal Enclosure– Power conditioning and distribution

Item	Mass [kg]	Source
Nadir Deck Enclosure	TBD	
Antennas - Uplink/Downlink	3	
Antenna - Reset Receiver	0.25	
Internal Enclosure (including estimated payload)	7.724	
Wiring	0.5	
Screws/harnessing	0.5	
Low Noise Amplifiers	0.5	
Combiner	0.25	
Frequency reference	0.5	
AstroSDR	0.3	Rincon– March 11, 2016
Heat Plate/RF Shield	0.1	
Local Oscillator	0.5	
Mixer	0.25	
Filter	0.1	
Phase shifter	0.4	
Splitter	0.25	
Transmit Driver Amp	0.25	
Power Amplifiers	0.25	
Power conditioning	0.5	
	Total:	
	16.124	

Internal Enclosure Preliminary Design



Internal Enclosure Preliminary Design



Part	Material	Mass
Lower Housing*	Al 6061	3.667 kg
Upper Housing*	Al 6061	3.307 kg
PC104 Card Cage	Aluminum, Steel, Silicone	approx. 0.75 kg
Total:		7.724 kg
*Fabricated at the Virginia Tech AOE Machine Shop		

IMAGE REDACTED

Internal Enclosure (payload)

- PC/104 Card Cage (Curtiss-Wright)
 - COTS component
 - 4", 6", 8", and 10" rail options
 - shock absorbers effectively reduce G-loads in 3 dimensions by up to a factor of 10
 - PC/104 PCB standards (approx. 90 x 96 mm)



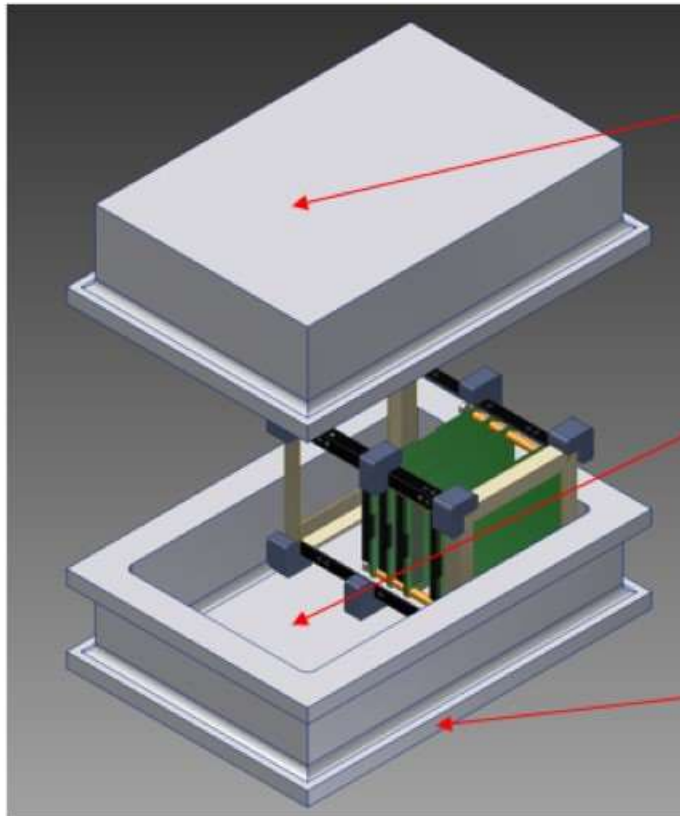
P/N	Description	Lead Time
PRV-1205-01	Non-Slotted Aluminum Rail Set, 4" Length, Holds up to 5 Cards	Ship 8-10 Weeks ARO
PRV-1206-01	Non-Slotted Aluminum Rail Set, 6" Length, Holds up to 8 Cards	Ship 8-10 Weeks ARO
PRV-1207-01	Non-Slotted Aluminum Rail Set, 8" Length, Holds up to 11 Cards	Ship 8-10 Weeks ARO
PRV-1208-01	Non-Slotted Aluminum Rail Set, 10" Length, Holds up to 14 Cards	Ship 8-10 Weeks ARO
PRV-0439-03	CARD CAGE ENDCAP, 4" X 4", W/3" SQUARE CUTOUT	Ship 8-10 Weeks ARO

Nadir Deck Enclosure

- Designed similar to the Internal Enclosure with additional room next to the PC/104 Card Stack to accommodate antenna

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REDACTED



Antenna
mounting area

Area for
antenna
internals

Payload
mounting area

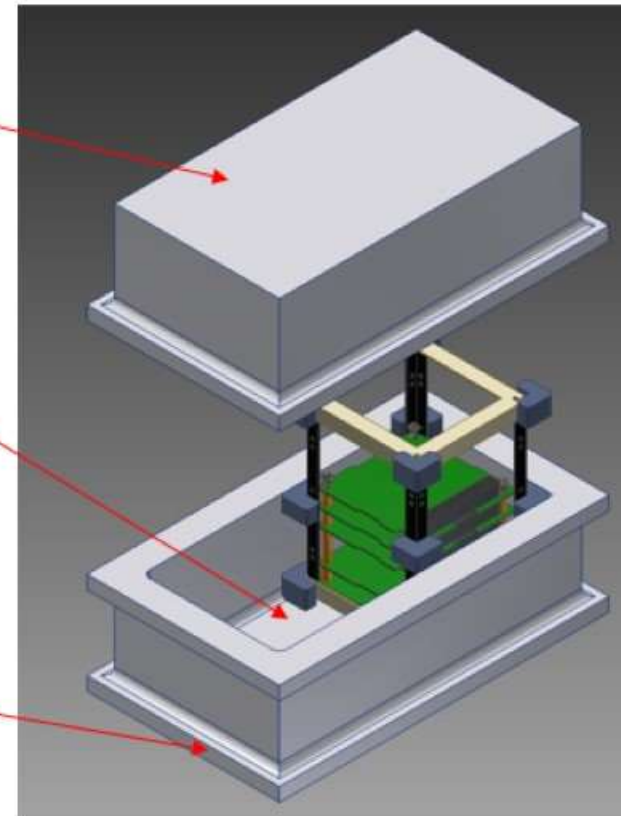
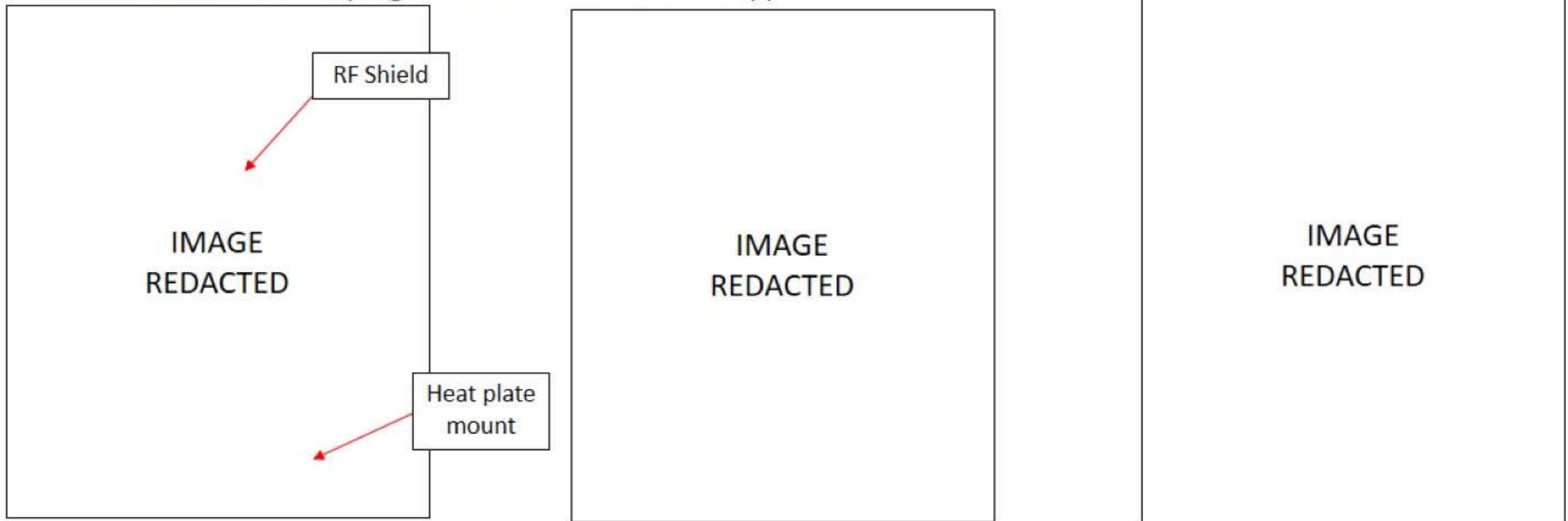


IMAGE
REDACTED

Nadir Deck Enclosure (AstroSDR)

- AstroSDR design conforms to the CubeSat Next Generation Bus (CNGB) specification
 - Contacted the distributors of the CNGB frame structure– direct purchase from vendor is not available at this time...
- Heat Plate
 - Designed to conform to PC/104 dimensions
 - Mounts directly to AstroSDR
 - Will securely mount to PC/104 Card Cage rails
 - Manufactured in-house (Virginia Tech AOE Machine Shop)



Preliminary Analysis (Internal Enclosure)

- Pressure Decay/Venting

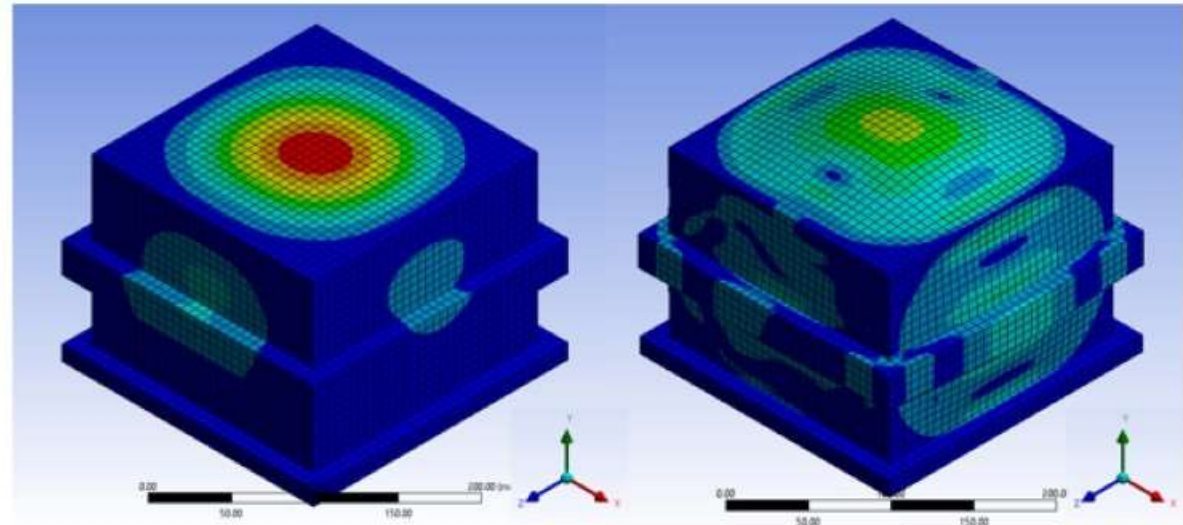
- REDACTED The Payload Provider shall design components to withstand a maximum pressure decay rate of REDACTED inside of the Payload fairing. Transonic spike(s) up to REDACTED REDACTED shall be acceptable.

IMAGE
REDACTED

- Preliminary Vent Design

- NASA JPL established an empirical rule for venting adequacy
 - If $V/A < 2000$ inches, then no further venting analysis needed
 - Internal volume, $V \approx 208$ in³
 - Venting area, $A = 0.346$ in² (10X Ø .210 inch venting holes)
 - Resulting $V/A = 600.53$ in

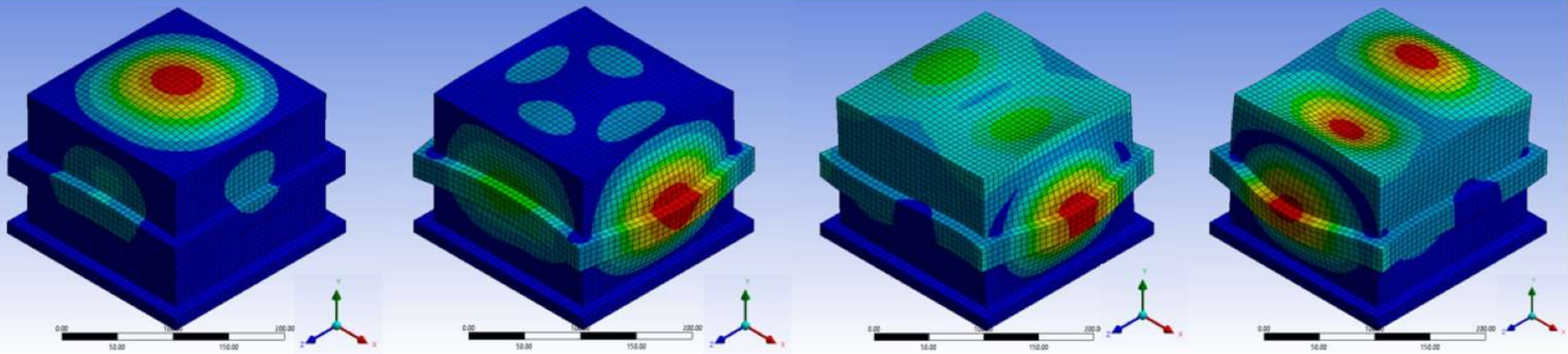
- Maximum 7.75e-3 mm deformation, 4.5 Mpa stress



Preliminary Analysis (Internal Enclosure)

- Modal Analysis

- REDACTED The fundamental mechanical mode of the Internal Enclosure shall be greater than REDACTED
 - 1st mode occurs at approximately 3000 Hz
- REDACTED The fundamental mechanical mode of the Nadir Deck Enclosure shall be greater than REDACTED



Preliminary Analysis (Internal Enclosure)

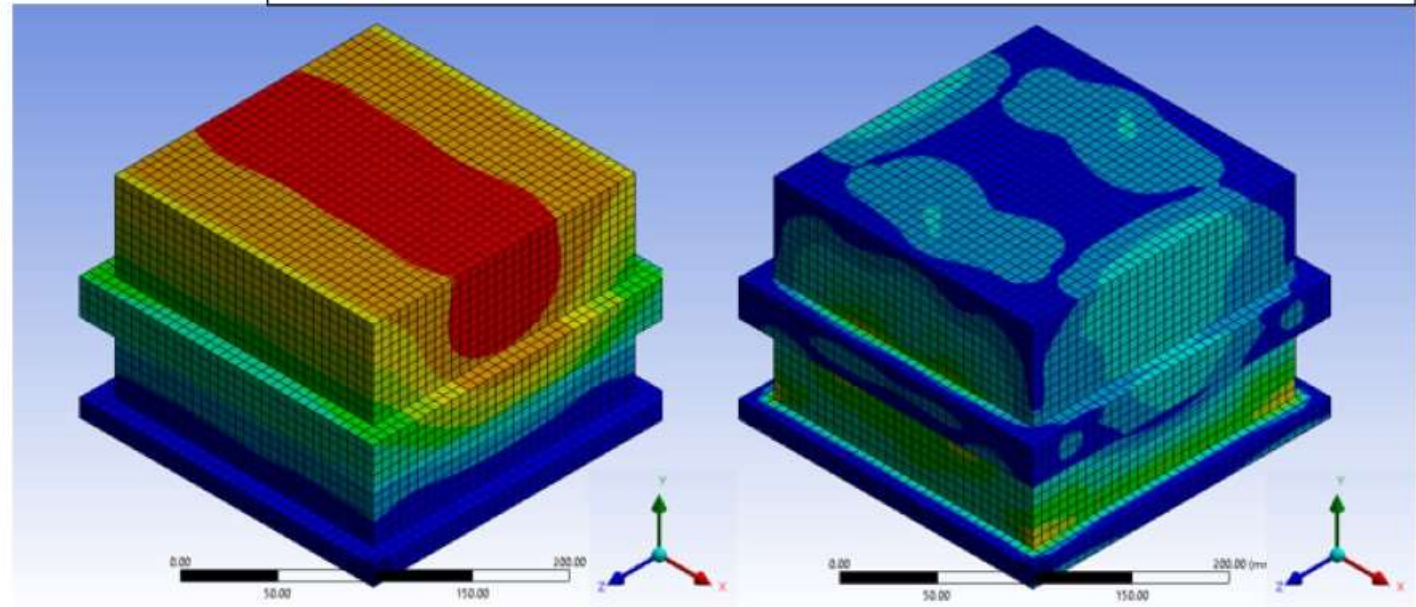
- Random Vibration

- REDACTED *The payload provider will test to the random vibration environment specified for a duration of REDACTED or longer per each of three orthogonal axes*

IMAGE
REDACTED

- Maximum deformation and stress occur from x-axis loading

- 1.50e-3 mm deformation
- 0.77 Mpa stress

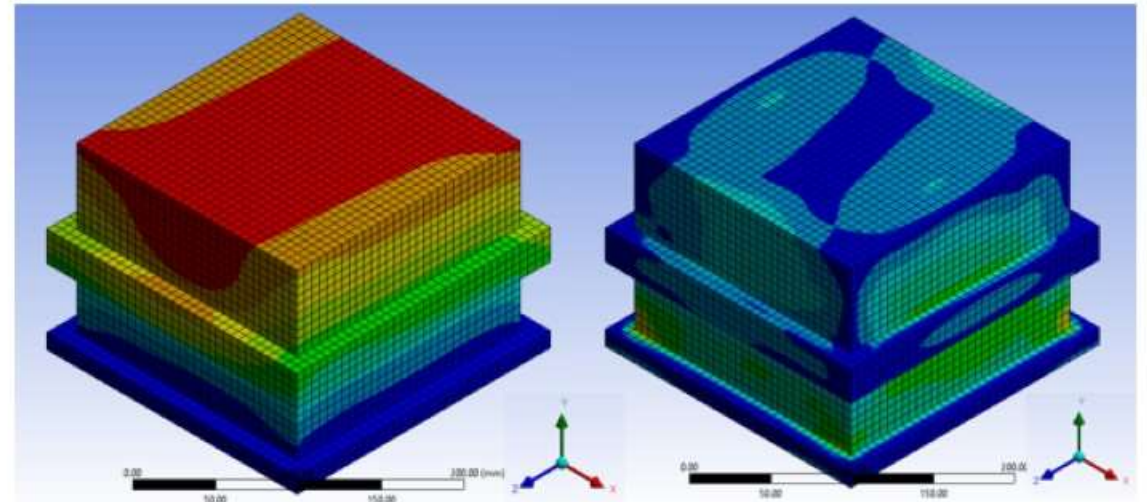


- Shock

- REDACTED *The internally mounted payload will be qualification tested in accordance with the shock spectrum shown. The spectrum shape will be controlled to within REDACTED and will be applied in each of three orthogonal axes. At least REDACTED spectrum amplitudes will exceed the nominal test specification.*

IMAGE
REDACTED

- Maximum deformation and stress occur from z-axis loading
 - 0.052 mm deformation
 - 27.3 Mpa stress



• Summer 2016

- Order PC/104 Card cages and obtain NDA for proprietary CAD models of PC/104 Card cage – 1 June 2016
- Finalized designs of both Nadir Deck and Internal Enclosures – 15 June 2016
- Order aluminum blanks from McMaster-Carr – 16 June 2016
- Engineering models sent in to machine shop – 24 June 2016
- Receive engineering models from machine shop – 22 July 2016
- Integrate engineering models for testing and evaluation – 27 July 2016
- Integrated engineering model tested in the VAST lab – 1 August 2016
- Post-process test data and compare/re-evaluate simulations – 4 August 2016

• Fall 2016

- Prepare to send detailed design unit to machine shop – 1 September 2016
- Integration – 1 November 2016
- Final Vibration and TVAC testing in the VAST Lab – 12 November 2016
- Receive validated final design from testing and evaluation – 12 December 2016
- Prepare for delivery – 19 Dec 2016

- Thermal/Vacuum: VAST lab, Langley, Wallops, Morehead St...
- Shake/vibration: **V**ibrations, **A**ddaptive **S**tructures and **T**esting (VAST) Laboratory at Virginia Tech
 - Zonic WCA Signal Analyzer: especially useful for experimental dynamic and acoustic structural analysis (also have SigLab and several other PC-based analyzers)
 - Newport vibration isolation table
 - Polytec PI Laser-Doppler Vibrometer and Scanner: allows mapping of modal data on surfaces of large structures. (e.g., PSV-400 with a 1 MGHZ range and close up modules, OFV-500 and PDV-100 portable units)
 - A 64-cubic feet environmental chamber is also available, allowing temperature and pressure controlled experiments



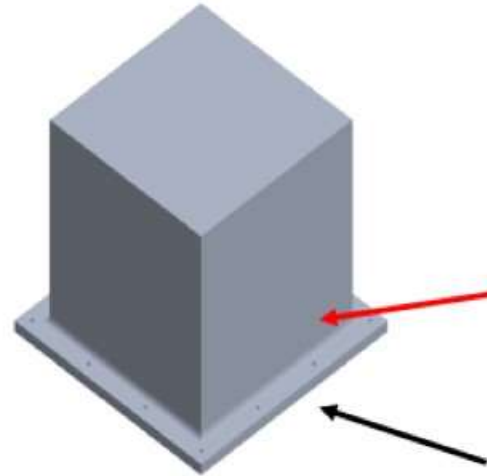
Tenneystrat Environmental
Test Chamber

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- Simulation Plan

- Perform 2 radiation thermal analysis' on external CAD drawing using SINDA and Thermica.
- Perform 2 conduction thermal analysis' on internal CAD drawing using SINDA and Thermica for the worst case conditions.
- For the "Hot case" $T = 80^{\circ}\text{C}$
- For the "Cold case" $T = -80^{\circ}\text{C}$

- Analysis Assumptions
 - dimensions based on "internal_rev2" drawing
 - box is coated with Z307 black paint ($\epsilon = 0.89$)
 - Thermally isolated from payload



Heat load = 20W on
baseplate
This is just an estimate.
Sil-Pad between box and
nadir deck. 0.733 to
 $1.315 \frac{W}{^{\circ}C \text{ in}^2}$

- Predictions
 - Box temperature range:
 $45^{\circ}C$ to $-38^{\circ}C$

- Simulation Plan

- Radiation flux produced by internal components is small compared to those produced by the Sun and Earth, therefore a radiation analysis is not necessary.
- Perform 2 conduction thermal analysis' on internal CAD drawing using SINDA and Thermica for the worst case conditions.
- For the "Hot case": 45°C
- For the "Cold case": -38°C

Thermal tolerance during launch

- Internal box temperature range of -38°C to 45°C .
- In order to keep SDR warm, implement heaters.
- Minco Polyimide Thermofoil Heaters can operate at a temperature range of -200°C to 200°C .



Size (inches)		Size (mm)		Type	Resistance in ohms*	Typical power	Effective area in ² (cm ²)	Lead AWG
X	Y	X	Y					
0.50	2.00	12.7	50.8	1 	157	5 W at 28 V	0.79 (5.10)	30
0.50	4.00	12.7	101.6	1 	78.4	10 W at 28 V	1.67 (10.77)	30
0.50	6.00	12.7	152.4	1 	52.3	15 W at 28 V	2.35 (15.16)	30

Watt Density for $T = -38^{\circ}\text{C}$

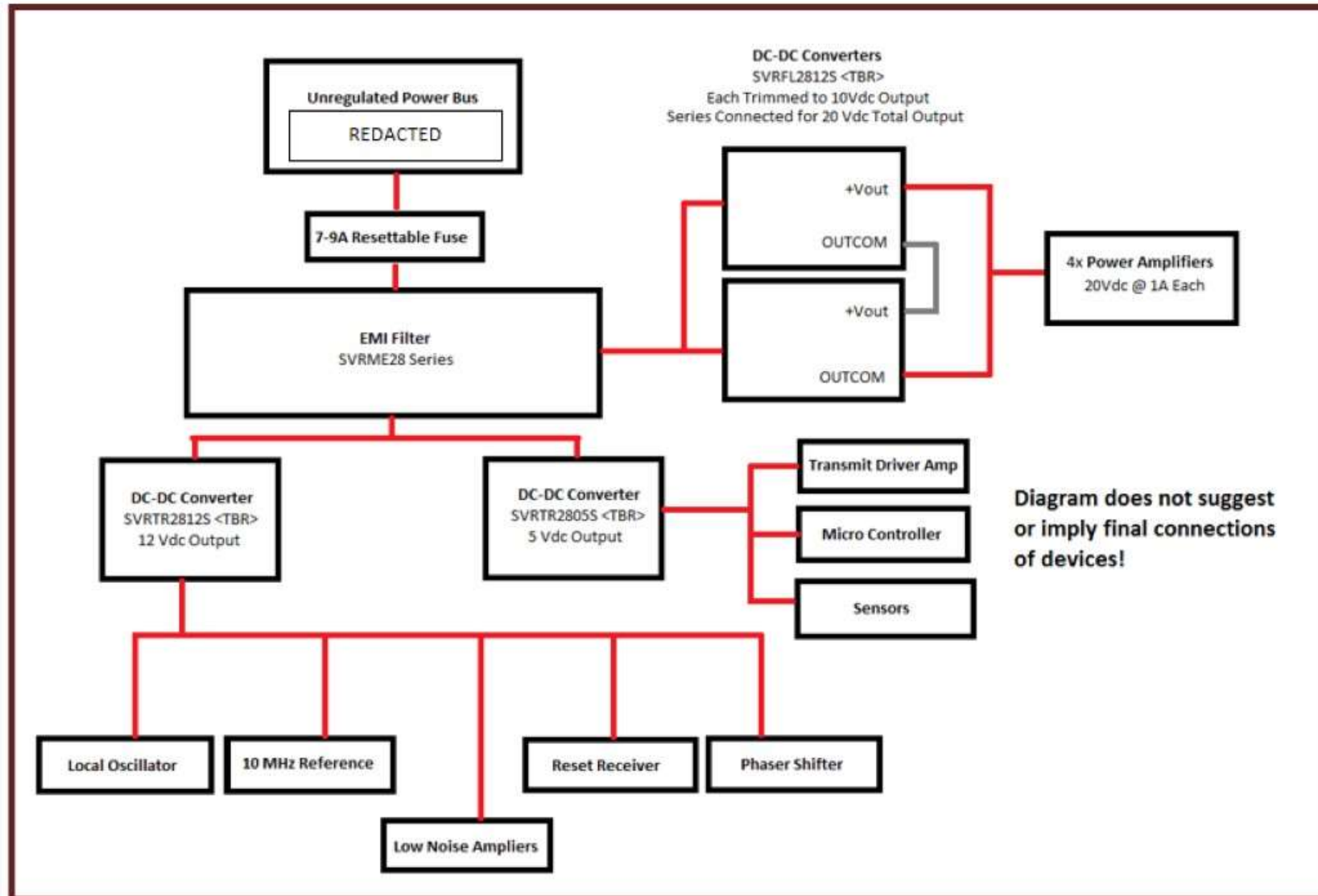
Mounting Method:

- Acrylic PSA = 20 W/in^2
- Epoxy = 47 W/in^2
- Stretch Tape or Clamped = 50 W/in^2

- Summer 2016
 - Complete initial SINDA tutorials and workshops– 29th July 2016
 - Complete thermal model of internal environment and recommend heater specs. – 28th August 2016
- Fall 2016
 - Complete thermal model of external environment – 28th October 2016
 - Have all thermal models completed with all final components incorporated – 1 Nov 2016
 - Software Load – 1 Dec 2016
 - Complete all thermal testing – 16th Dec 2016
 - Finish a short report/summary on thermal environment and solutions – 31 Dec 2016

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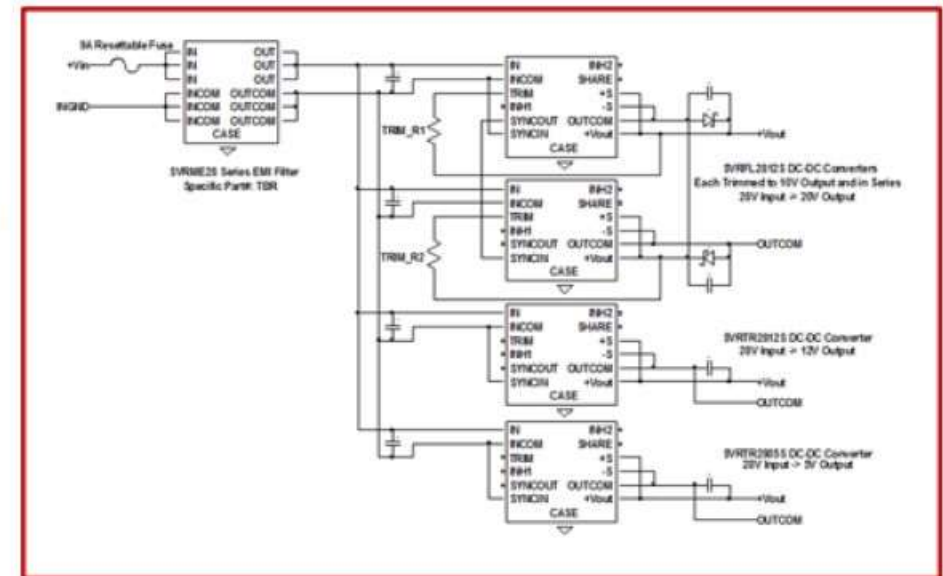
Power Distribution Layout



- Currently at 4 DC-DC Converters and a EMI Filter from VPT.
 - Close proximity (at the CRC)
 - Already tested to be space-rated and rad-hard/tolerant
 - Can be used in conjunction with capacitors and diodes to deal with transients and in-rush currents
 - Possible limitations due to size and weight?
- Power efficiency expected between 80 to 86%
 - EMI Filter power lost is 9W
- Possible low lead times



SVRME Series EMI Filter



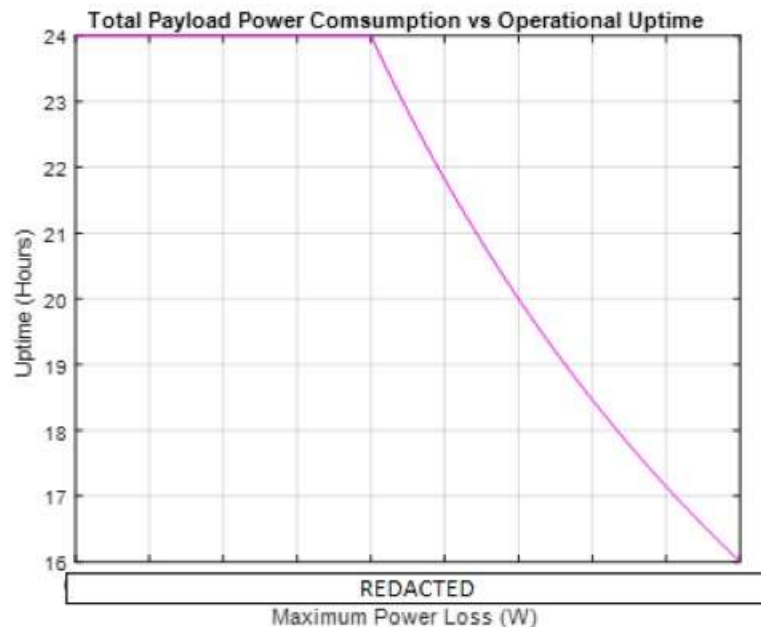
One Possible Power Conditioning Design

Items	Max Expected Power Drain	Average Voltage	Average Current
AstroSDR	20 W (typical drain of 12W-18W)	12 V dc (7V-13.2V dc raw input)	1.7 A
Power Amplifier (for each of 4 antennas)	80 W (total)	20 V dc (per antenna)	1 A (per antenna)

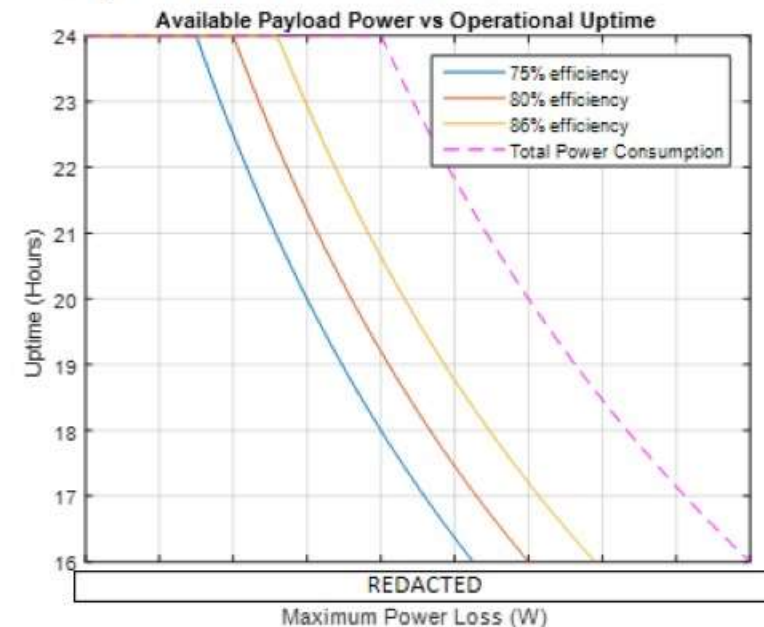
Items Still Under Review	Estimated Power Drain
Microcontroller	0.25 W
Low Noise Amplifiers	5 W
10 MHz Reference	5 W
Local Oscillator	5 W
Phase Shifter	2 W
Transmit Driver Amp	3 W
Reset Receiver	0.5 W
Sensors	1 W
EMI Filter	9 W

- Many components or devices have not been finalized.
 - High-end estimations based on previous experiences
- Estimated power drain, after efficiency lost at full load, is 130.75 W.

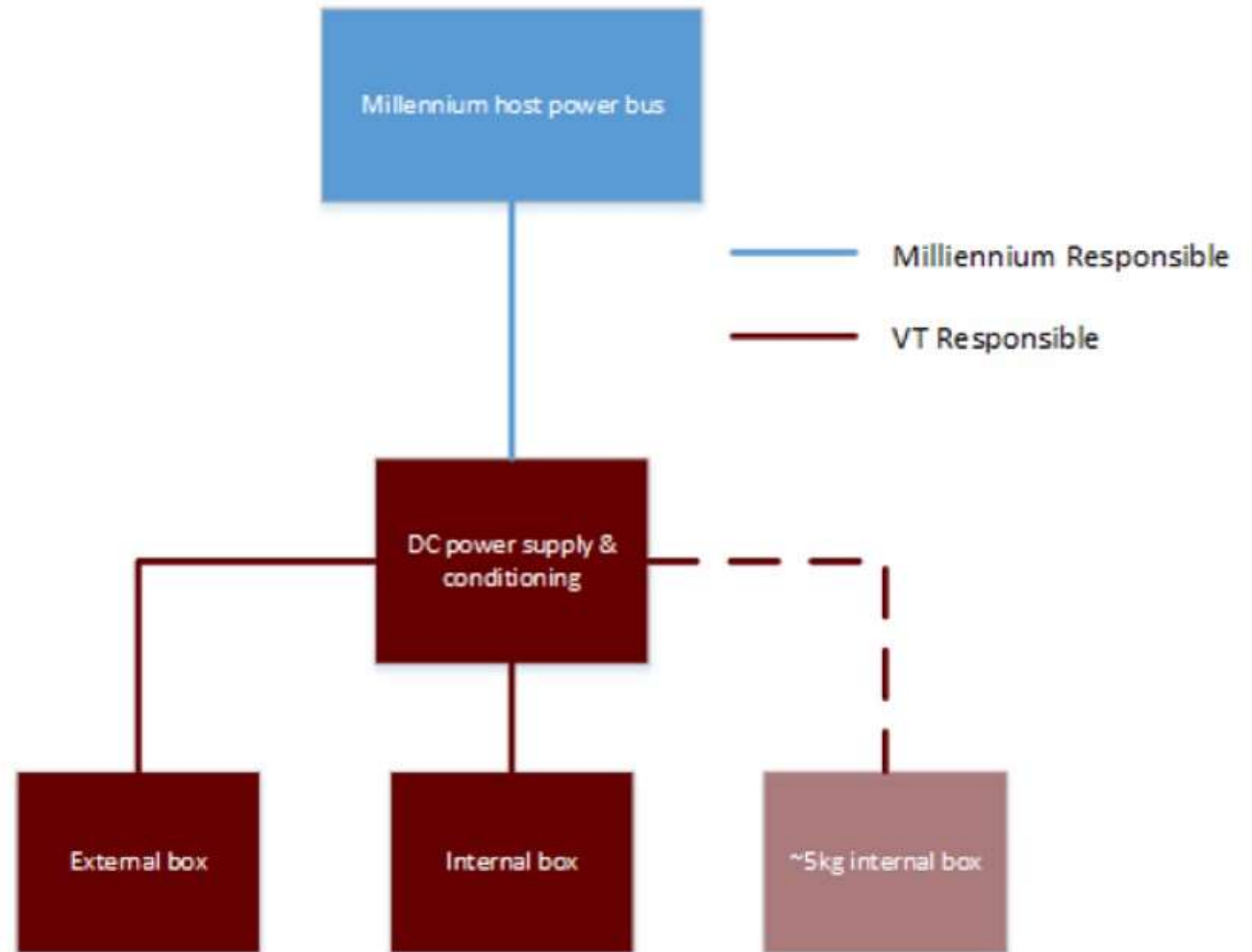
- First look at power conservation involved the idea to “turn on” and “turn off” the payload’s components as needed
 - Required a lot of overhead
 - Greatly limits active operational time
 - Was limited by what we didn’t know at the time (component power cost)



- Reviewed the issue after getting a better idea of possible power efficiency numbers
- By keeping efficiency >80% , we can stay on at all times at 80W (the equivalent of disabling two power amplifiers)
- Can temporarily enable the other two amplifiers with the proper amount of overhead beforehand
 - Requires further review



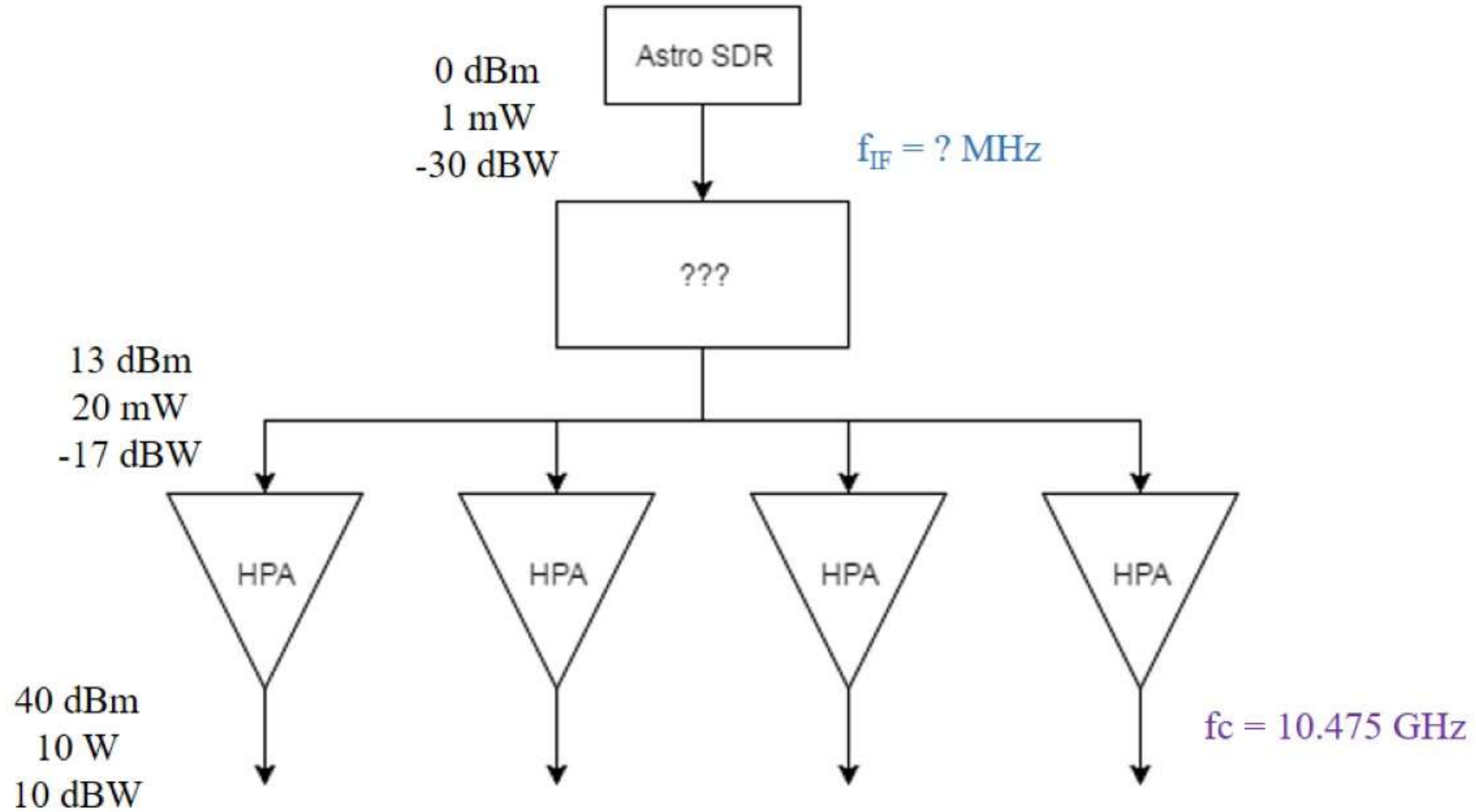
- Payload/host interconnect: wire, connectors to interface with Millennium host are TBD from Millennium
- Payload-subsystem interconnects: VT will determine and be responsible for these. Still TBD based on power requirements



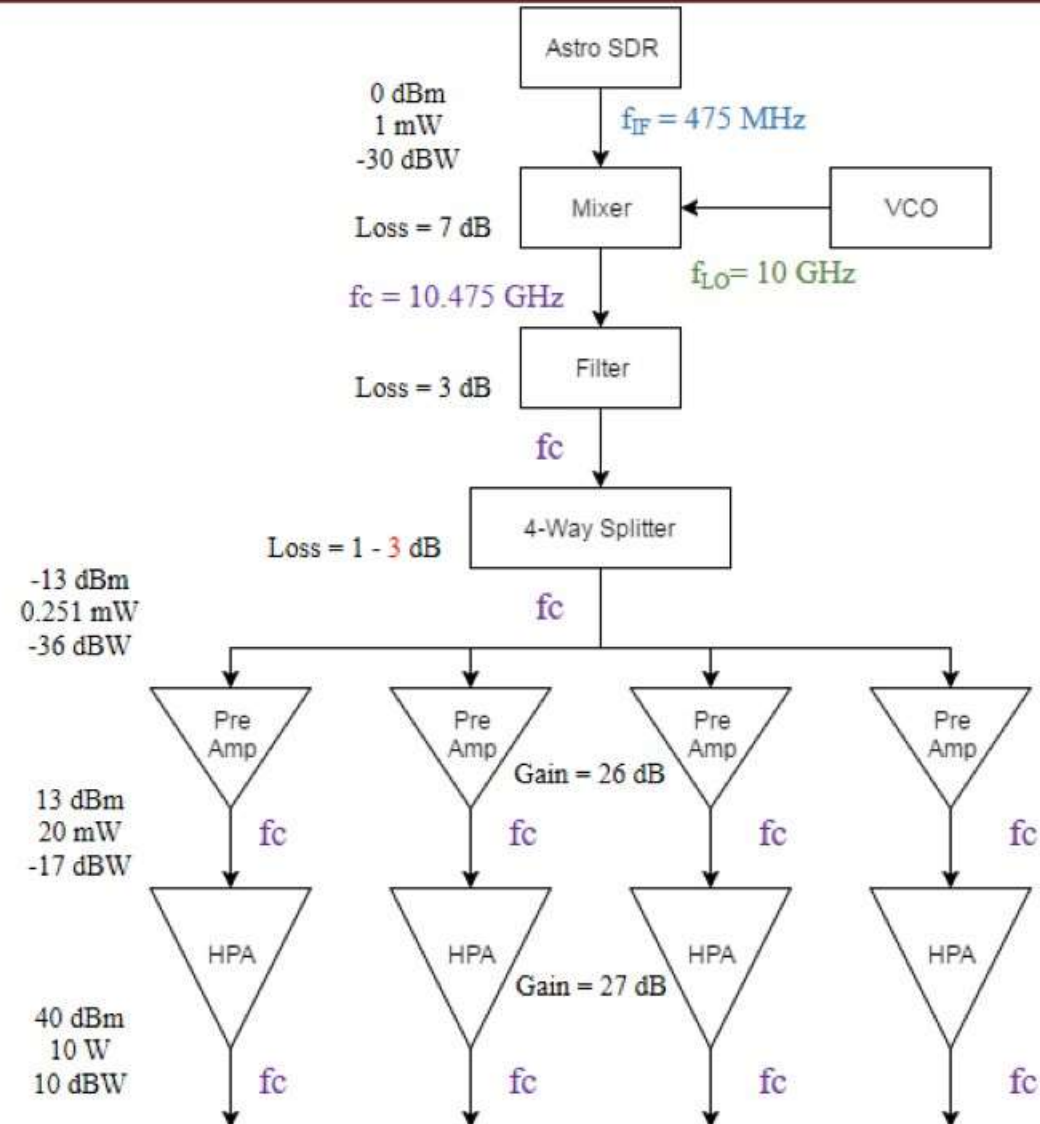
- Summer 2016
 - Finalize resettable fuse design – 1 July 2016
 - Finalize EMI filtering – 10 July 2016
 - Preliminary DC-DC conversion design – 5 August 2016
 - Preliminary host interconnects – 5 August 2016
 - Preliminary wiring harnesses & distribution – 5 Aug 2016
- Fall 2016
 - Finalize DC-DC conversion design – 20 September 2016
 - Finalize host interconnects – 1 October 2016
 - Finalize wiring harnesses & distribution – 15 October 2016
 - Integrate into payload – 1 November 2016

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Transmitter Starting Point



Potential Transmitter Architecture



Potential Mixers

Device	Analog Devices HMC-C049	Marki Microwave IRW-0618	Analog Devices HMC1056LP4BE	Analog Devices HMC9059
Type	Passive Double Balanced GaAs MMIC	Passive Image Reject	Passive Image Reject GaAs MMIC	Active Image Reject GaAs MMIC
RF Frequency (GHz)	7.0 – 11.0	6.0 – 18.0	8.0 – 12.0	9.5 – 13.5
LO Frequency (GHz)	7.0 – 11.0	6.0 – 18.0	8.0 – 12.0	6.0 – 17.0
IF Frequency (GHz)	DC – 5.0	DC – 0.210	DC – 4.0	2.0 – 8.0
LO to RF Isolation (dB)	48	35	40	10
LO to IF Isolation (dB)	35	25	35	40
RF to IF Isolation (dB)	22	25	Not Rated	Not Rated
Conversion (dB) Loss(-)/Gain(+)	-7	-7.5	-8	+15
Sideband Rejection (dBc)	Not Rated	23	25	22

Double Balanced vs. Image Reject

Device	Analog Devices HMC-C049	Marki Microwave IRW-0618
Type	Passive Double Balanced	Passive Image Reject
IF Frequency (GHz)	.475	.175
LO Frequency (GHz) [Low Side Injection]	10	10.3
RF Frequency (GHz) [LO+IF]	10.475	10.475
Image Frequency (GHz) [LO-IF]	9.525	10.125
Image Filter	Required	Not Required
LO to RF Isolation (dB)	48	35
LO to IF Isolation (dB)	35	25
RF to IF Isolation (dB)	22	25
Conversion (dB) Loss(-)/Gain(+)	-7	-7.5
Sideband Rejection (dBc)	Not Rated	23

Voltage Controlled Oscillator

- Device: TGV2563-SM
- Frequency Range: 9.7 – 10.8 GHz
- Tune Voltage: 2 – 13 V
- Output Power: 11 dBm
- Bias: $V_{cc} = 5\text{ V}$, $I_{cc} = 175\text{ mA}$
- Power Dissipation = 0.875 W
- Storage Temperature = $-65^{\circ}\text{C} - 125^{\circ}\text{C}$
- Tested Operating Temperature = $-40^{\circ}\text{C} - 85^{\circ}\text{C}$
- May need Phase Locked Loop Circuit



32-pin 5x5mm package

Potential Pre-Amplifiers

Device	Analog Devices HMC608LC4	Qorvo (TriQuint) TGA2501-GSG	Qorvo (TriQuint) TGA2625
Frequency (GHz)	9.5 – 11.5	6.0 – 18.0	10.0 – 11.0
Gain (dB)	29.5	26	37
Vd (V)	5	8	28
Output IP3 (dBm)	33	Not Rated	Not Rated
Output P1dB (dBm)	27 , Pin = -4 dBm	34* , Pin = 10 dBm	~ 42 , Pin = 7 dBm
Output Power (dBm)	20 , Pin = -10 dBm	16* , Pin = -10 dBm	27* , Pin = -10 dBm
PAE (%)	~ 7.5 , Pin = -10 dBm	32 , Pin = 15 dBm	> 15* , Pin = -10 dBm
Power Dissipation (W)	~ 1.55	~ 9.6	~ 10.22

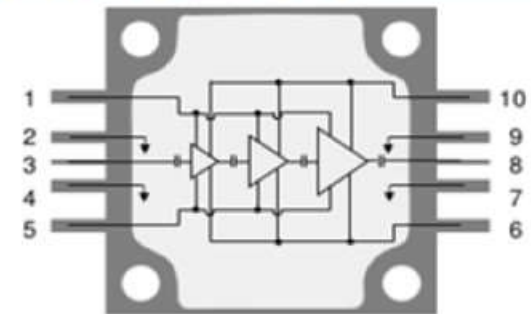
* Extrapolated Qualitative Estimation from Data Sheet

High Power Amplifier

- Device: Qorvo TGA2625-CP
- Frequency: 10 GHz
- Gain: 27 dB at 1-dB compression
- PAE: 45-50%
- Drain Voltage: 20V
- Power Dissipation = 20 W
- P_{out} : 10W (46 dBm) @ $P_{in} = -13$ dBm, Saturation
- Storage Temperature = $-55^{\circ}\text{C} - 150^{\circ}\text{C}$
- Tested Operating Temperature = $-40^{\circ}\text{C} - 85^{\circ}\text{C}$



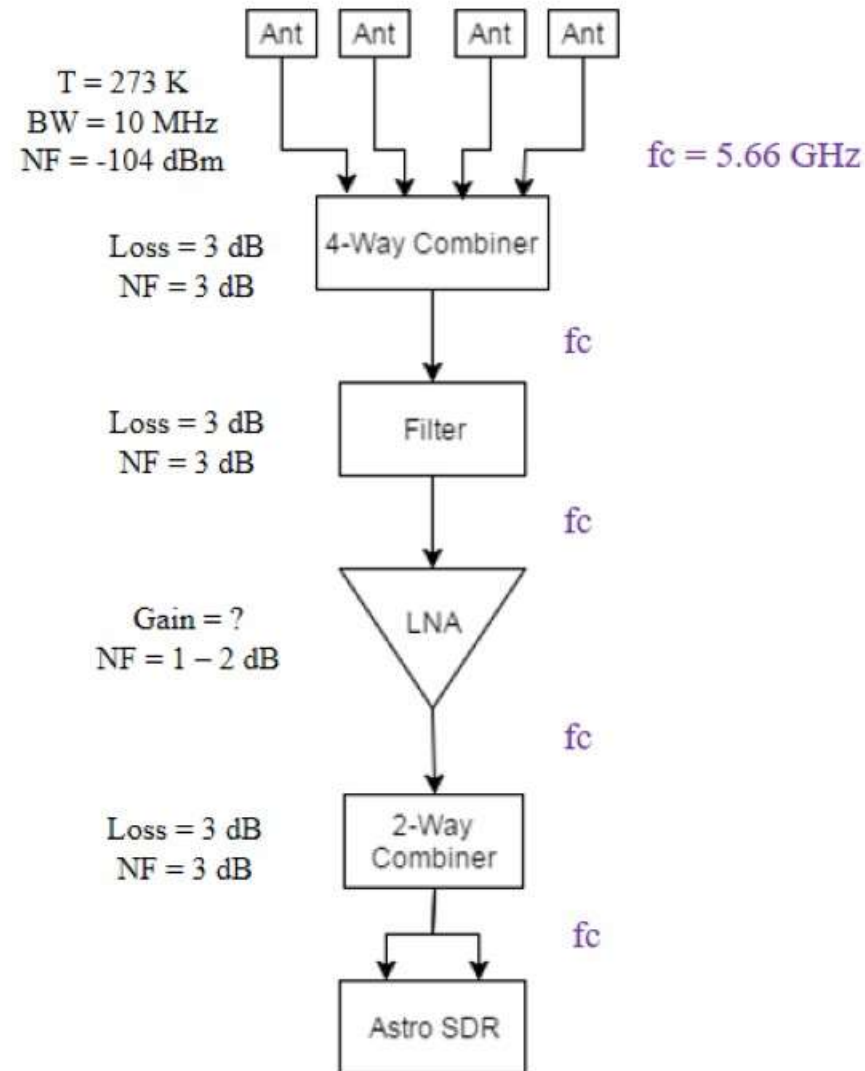
Functional Block Diagram



Pin Configuration

Pad No.	Symbol
1, 5	V_G
2, 4, 7, 9	GND
3	RF_{IN}
6, 10	V_D
8	RF_{OUT}

Potential Receiver Architecture

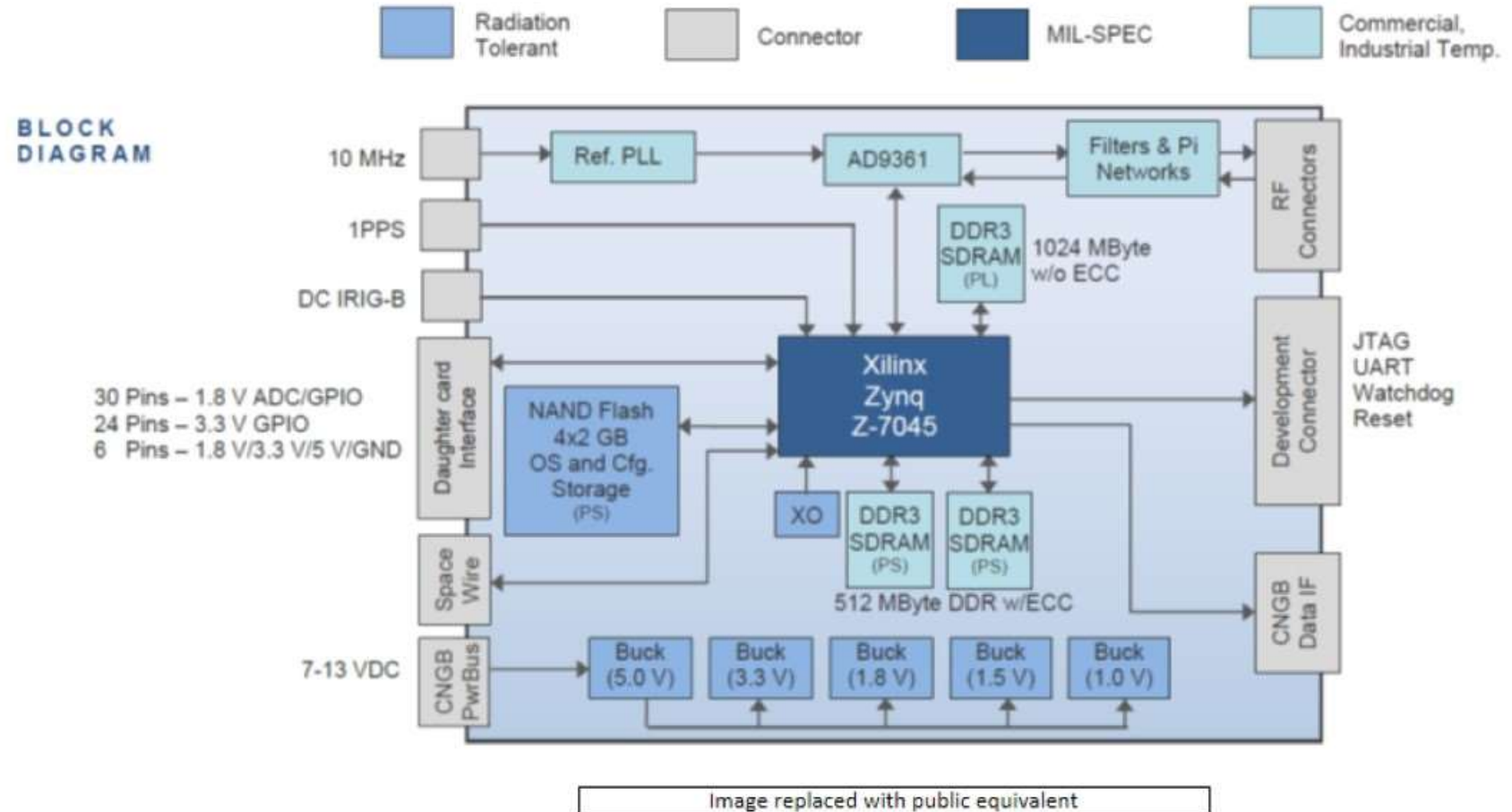


Device	Qorvo (TriQuint) TQP3M9037	Qorvo (TriQuint) TGM2543-SM	Qorvo (TriQuint) TGA2512-SM	API Tech Corp (Spectrum Microwave) BXHF1070
Frequency (GHz)	0.7 – 6.0	4.0 – 20.0	4.0 – 14.2	5.0 – 10.0
Gain (dB)	11	17	25	13
Noise Figure (dB)	1.2	1.7	2.5	3.8
Output IP3 (dBm)	31	30	21	41
Output P1dB (dBm)	22	18	12	30
Vd (V)	5	5	5	12
Power Dissipation (W)	0.35	0.5	0.8	5.28
Additional Capability	AGC	AGC & Limiter	AGC	

- Summer 2016
 - Mixer Analysis and Design – 8 June 2016
 - Image Filter Design & 4-Way Splitter Selection – 15 June 2016
 - Voltage Controlled Oscillator Analysis and Design – 22 June 2016
 - Pre-Amplifier Analysis and Design – 29 June 2016
 - LNA Design – 6 July 2016
 - LNA Filter Design – 13 July 2016
 - Order Parts and Get Price Quotes – 31 August 2016
- Fall 2016
 - Test individual RF components – 7 September 2016
 - Build RF transmit chain prototype – 5 October 2016
 - Test RF transmit chain prototype – 26 October 2016
 - Build RF receive chain prototype – 9 November 2016
 - Test RF receive chain prototype – 30 November 2016
 - RF Design Integration with Payload – 31 December 2016

- Introductions, Mission Overview & Motivation
- Mechanical Design
- Thermal Design
- Power Supply Design
- RF Design
- **AstroSDR Review**
- Reset Receiver Design
- Communications Software Architecture
- Antenna Design & Link Budget Analysis

- Receiving “serial -015”
- Xilinx Zynq 7045
All-Programmable SOC
- AD9361(Catalina) - 2x2
RF Agile Transceiver
- High reliability boot and
OS storage
- High reliability power
supplies

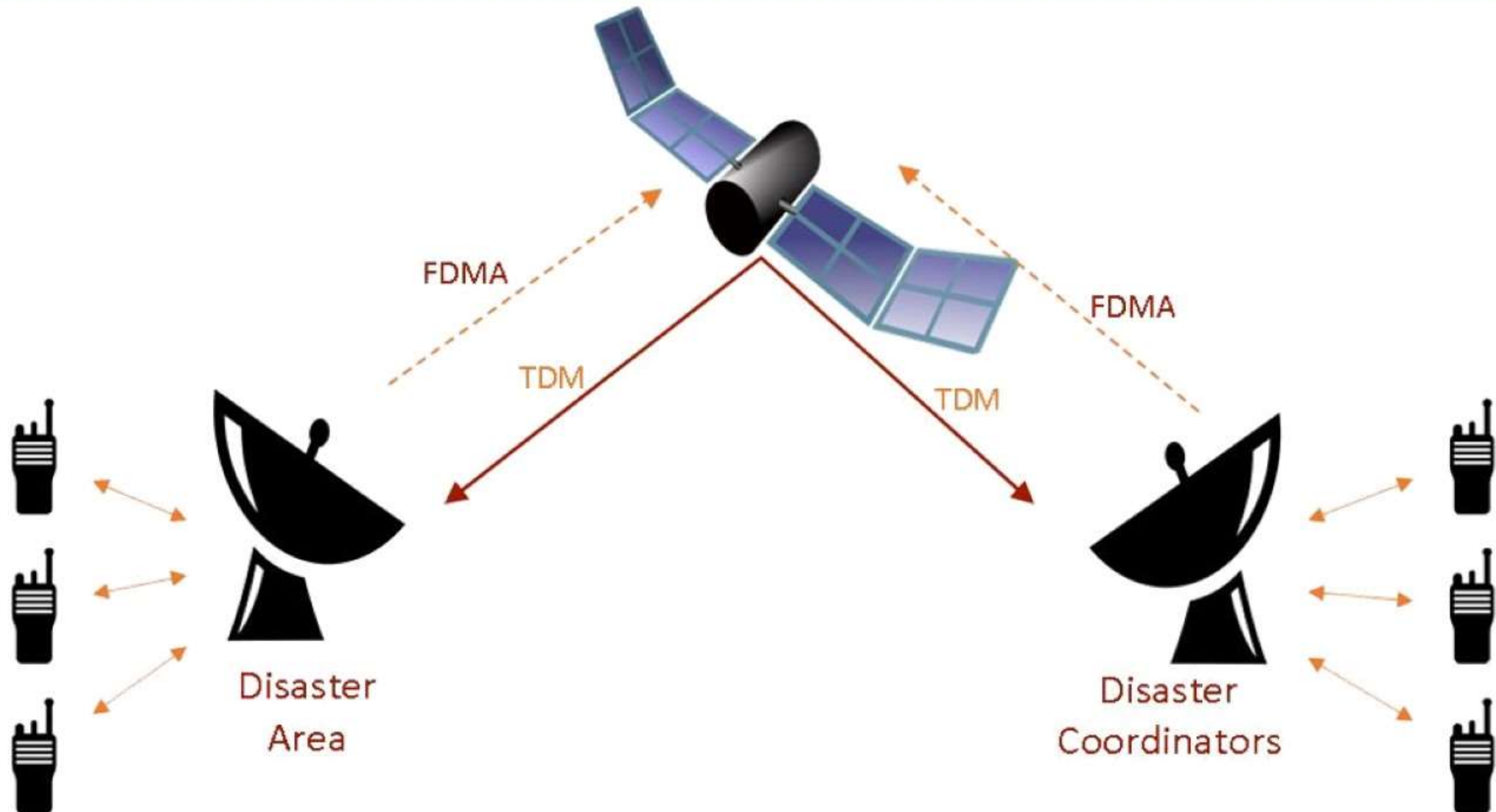


- Further slides redacted due to propriety information to Rincon Reserach

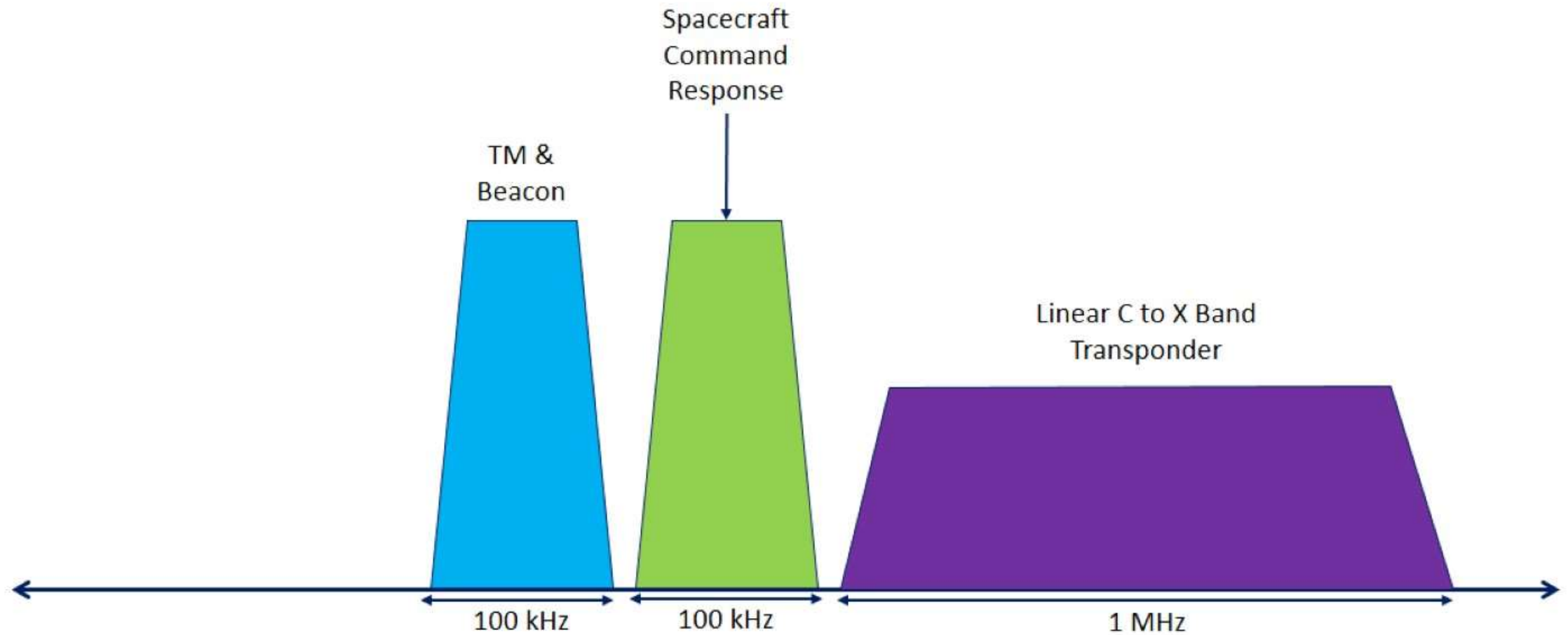
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- Reset receiver design slides redacted due to proprietary information of AMSAT - North America.

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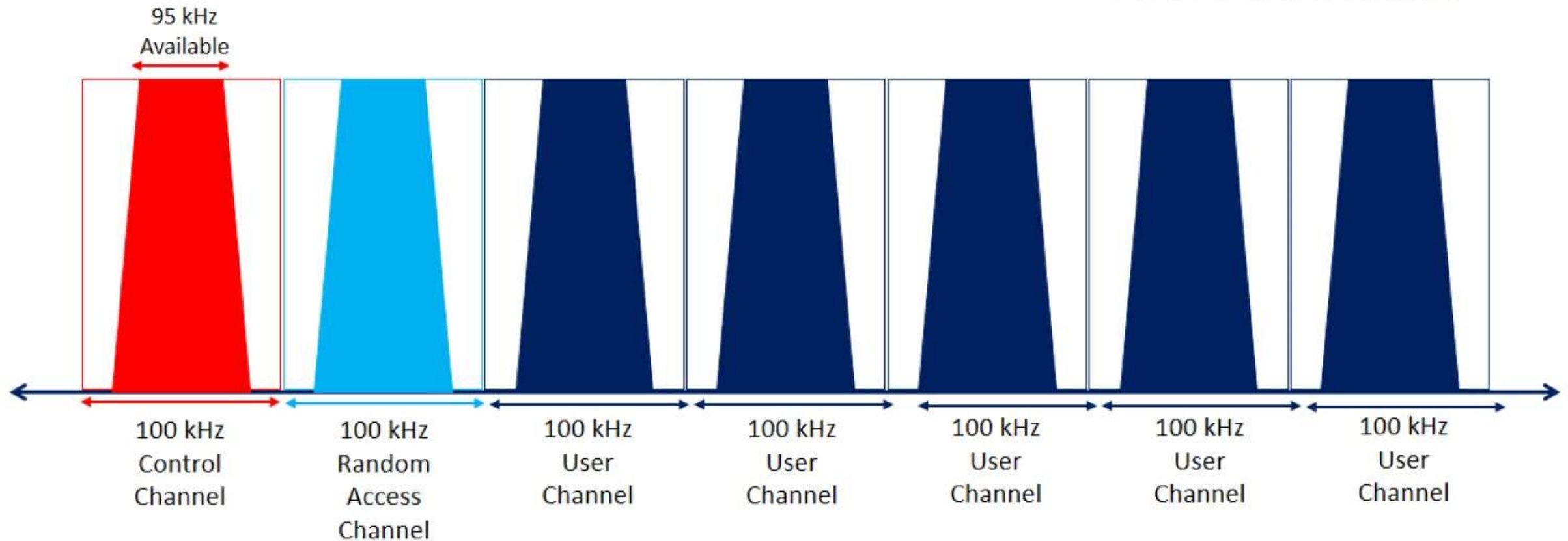


Initial Software Payload - Downlink



Minimum Uplink Design

10 MHz Uplink → 100 – 100 kHz Channels → { 90 User Channels
3 Control Channels
7 Random Access Channels



Assuming 95 kHz Available for Users

$$R_b = \frac{r \text{ 95 kHz}}{\log_2(M) (1 + \alpha)}$$

M is the modulation order

α is the rolloff factor of RRC Filter

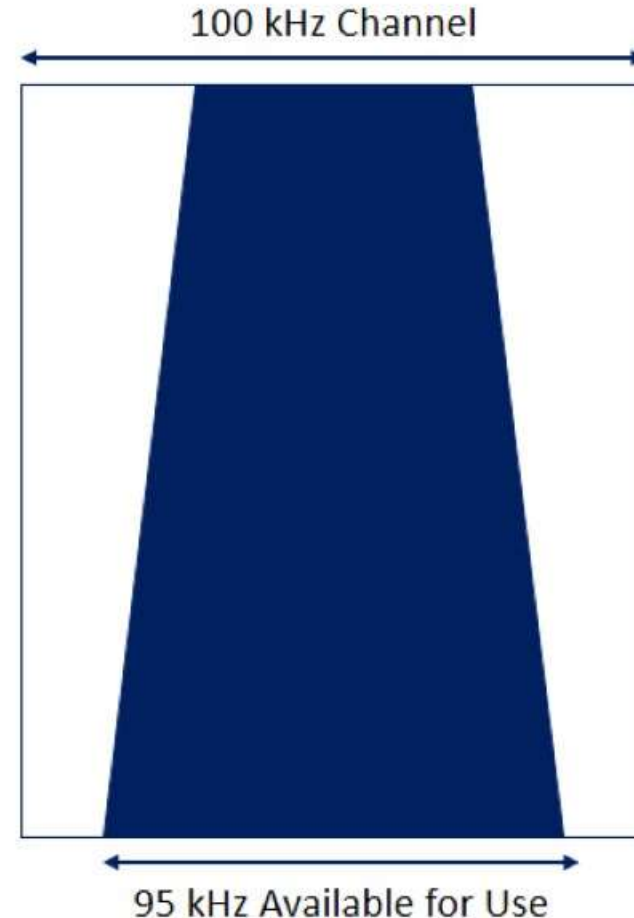
r is the total code rate used

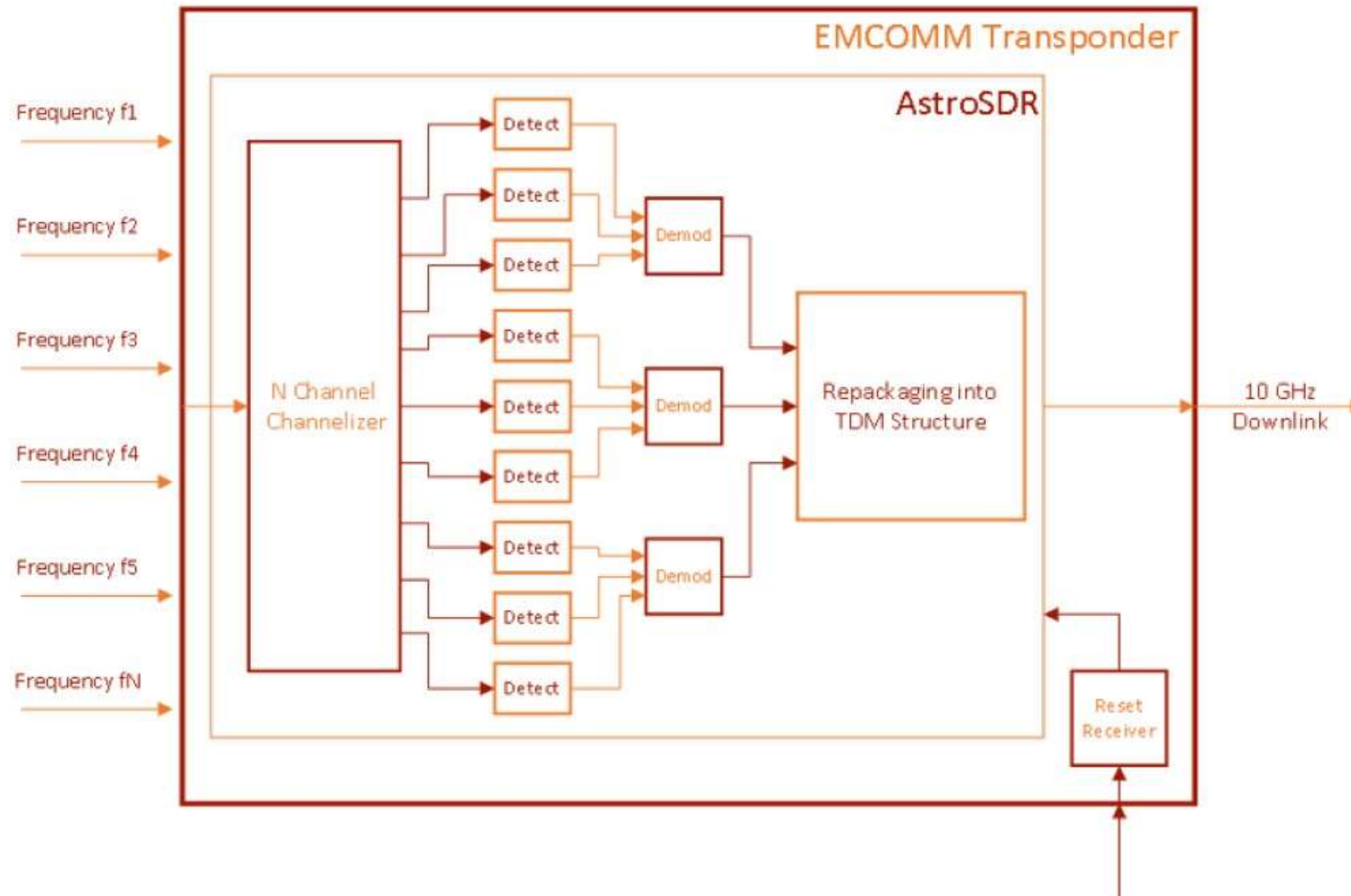
R_b is the bit rate

Example:

QPSK 13/45 ($r = 93/95 * 13/45$) with $\alpha = 0.33$

$$R_b = 10.2 \text{ kbps}$$





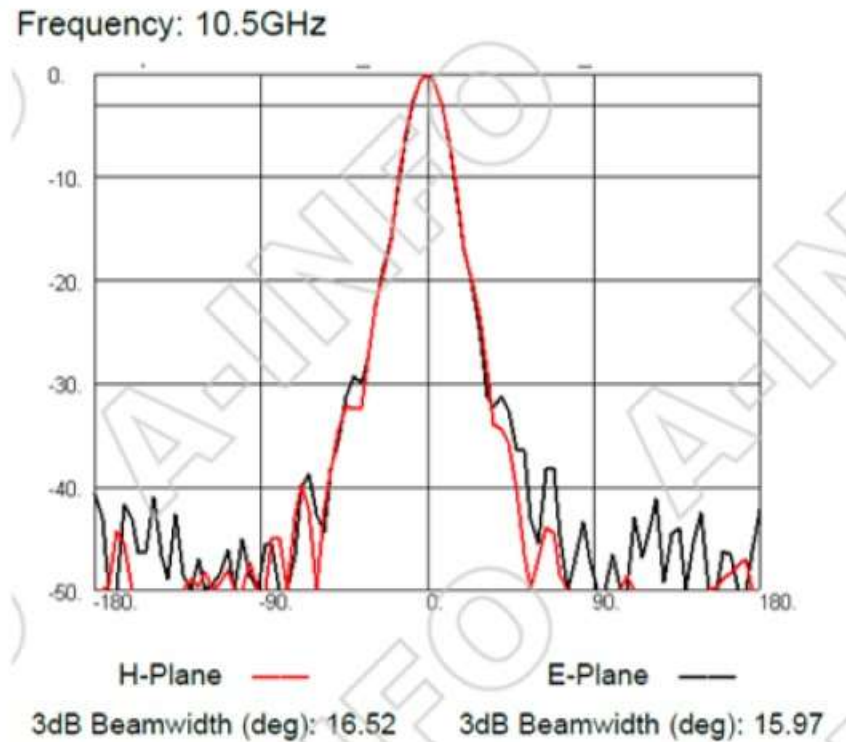
- There will need to be verifications during (if allowed) and after each test.
- There will need to be software and hardware checks that are done in software to ensure we maintain functionality of all parts during test
- We may not be able to transmit during these tests, so we will need to have checks that can be run without this
 - This could also be used if the transponder is in transfer orbit

- Summer 2016
 - Initial GNURadio Demo – 3 June 2016
 - Initial Uplink/Downlink Design – 1 July 2016
 - Complete GNURadio Demo – 15 Aug 2016
- Fall 2016
 - Payload Test Software – 1 Sept 2016
 - RFNoC Implementation – 1 Nov 2016
 - Software Load – 1 Dec 2016
 - Software Test Finished – 31 Dec 2016

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- Geosynchronous Orbit @ Orbital Slot REDACTED (assume 4 deg inclination)
- CONUS Coverage
- 40W TX Power
- Linear Polarization
- 10 MHz Noise Bandwidth
 - Since Downlink is single TDMA Stream, Ground Stations will have to receive the ENTIRE Aggregate 10 MHz.
- 0.6m G/S Diameter Reflector Antenna
- No or minimal Tracking required on the ground.
- Beam steering on S/C is desirable.
 - Downlink only for Security reasons.
- DVB-S2 and DVB-S2X Protocol

- Surveyed commercial available antennas
- Corrugated conical horn (A-Info)
 - Frequency: 8.2 – 12.4 GHz
 - Gain: 20.5 dB
 - REDACTED
 - 3 dB BW: 16° to 16.5°
 - Mass: ≈ 1.7 kg



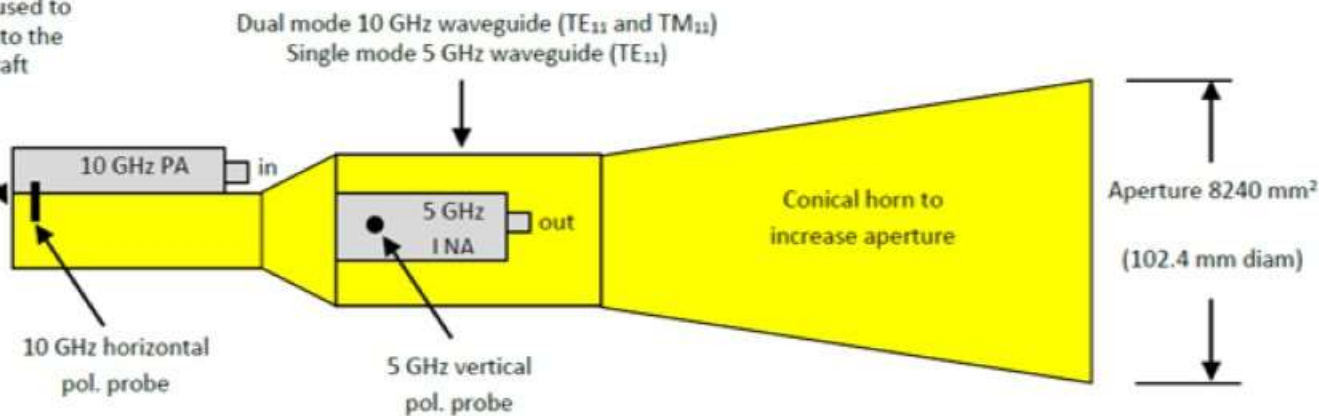
Antenna Design – Dual-band horn

- Option to combine uplink/downlink into one antenna

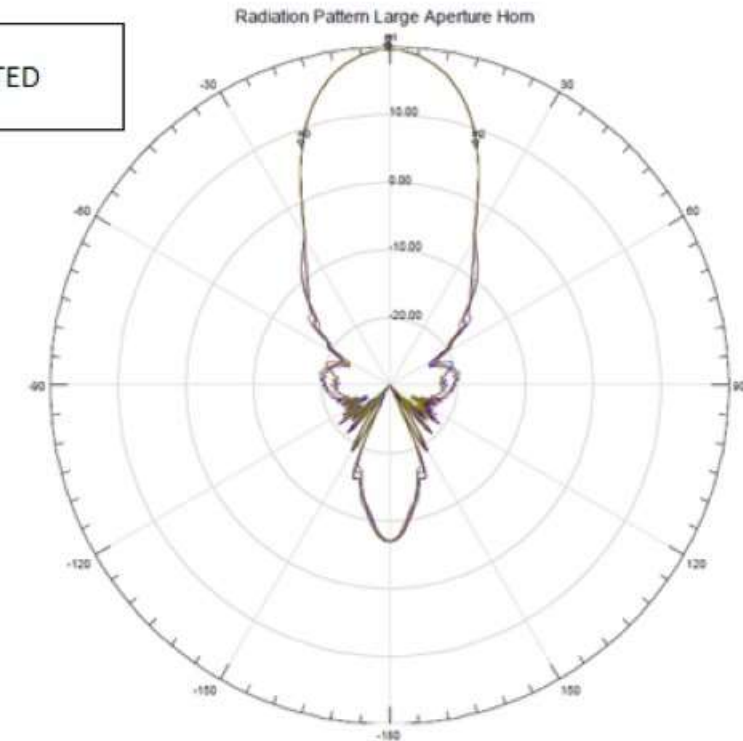
- Gain: 19.6 dBi

REDACTED

This face can be used to dissipate heat into the main spacecraft



REDACTED



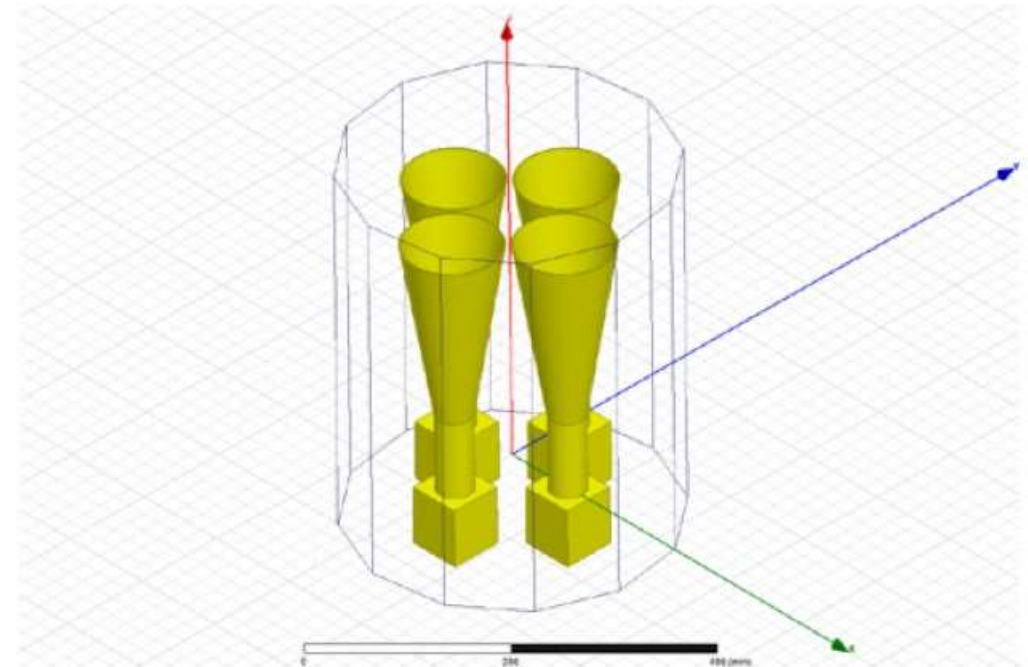
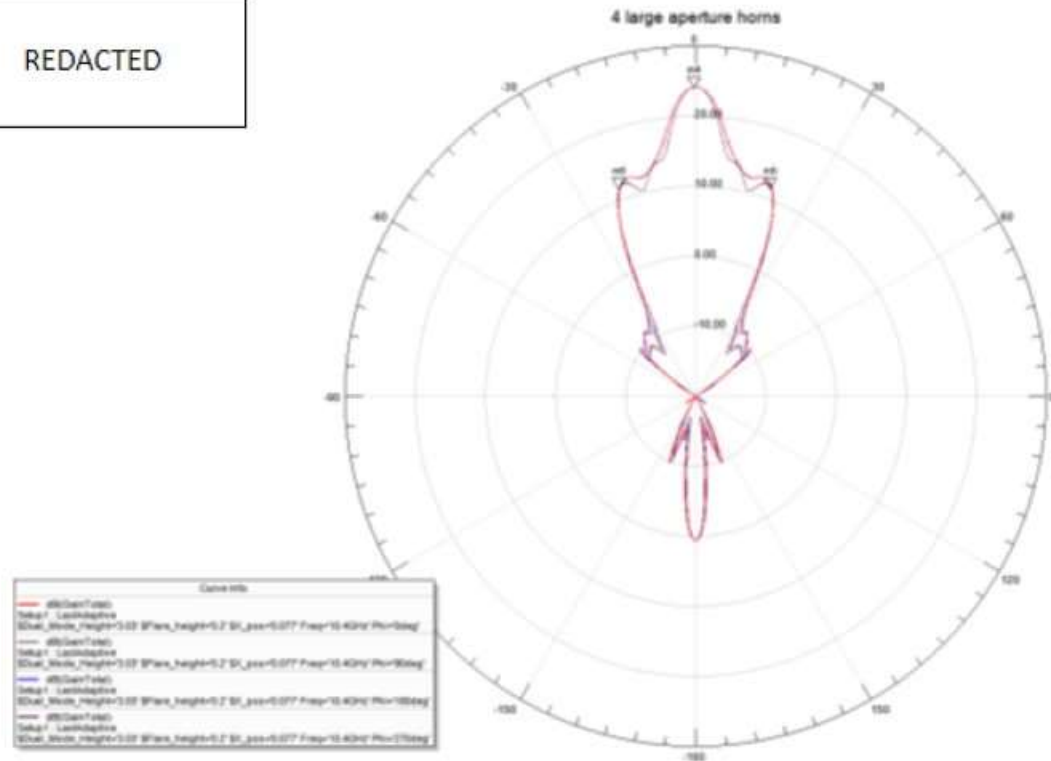
Antenna Design – Dual-band horn array

- To do beam steering, make an array of 4 horns

- Gain: 24.2 dBi

REDACTED

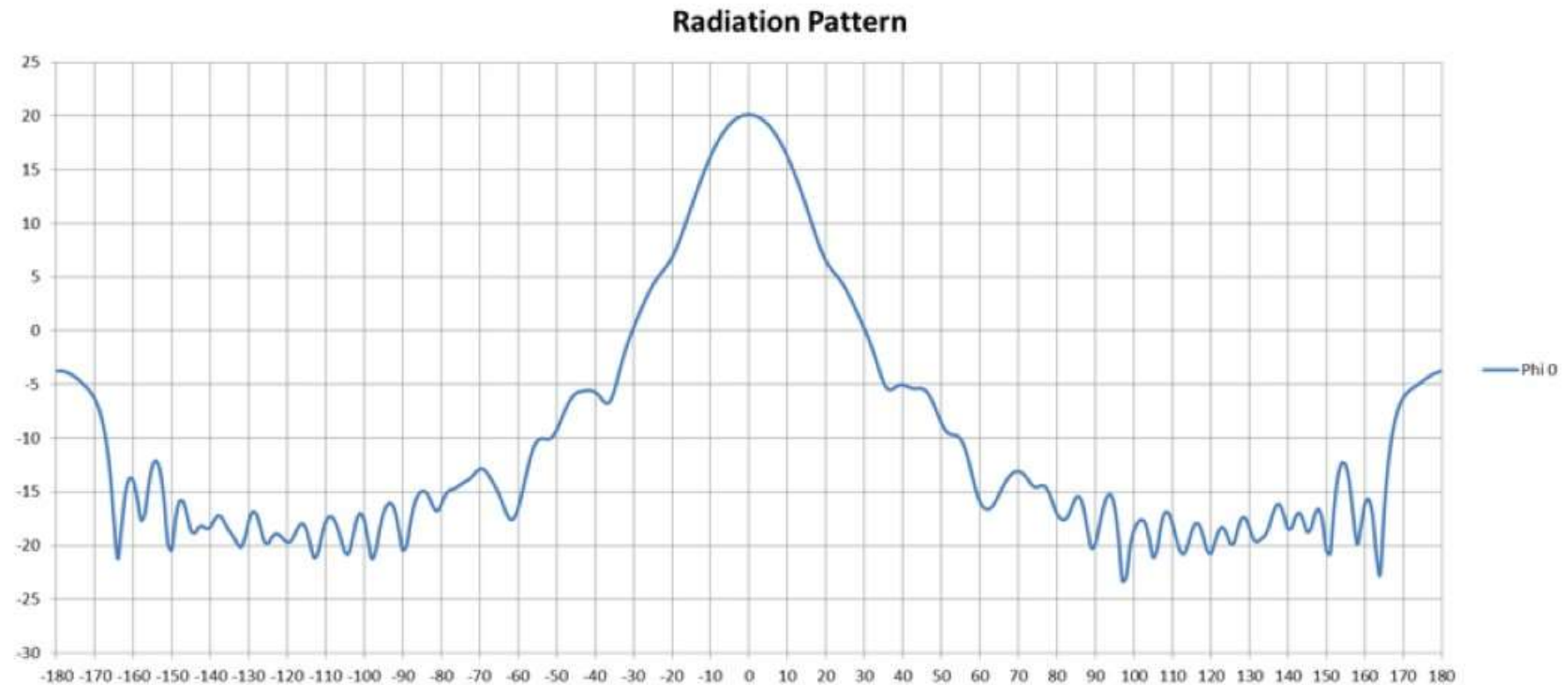
REDACTED



Antenna Design – Conical horn

- For use on the downlink
- Challenge is wide-enough main beam with quick rolloff
- Gain: 20.1 dBi
- 3 dB BW: 18°

REDACTED



Assumptions

- Center Frequency: 10.475 GHz
- Target BER 10^{-5} or better
- 1.0 dB implementation Loss
- RX System Noise Figure: 1.3 dB (<1.0dB NF LNA/LNB mounted close to feed)
- RX System Antenna Efficiency: 55%
- Phase Shift Keying modulations (BPSK/QPSK/8PSK) from DVB-S2(X) standards. (No QAMs due to saturated transponder PAs)
- -3.0 dB contour Loss
- NO polarization Loss (assume the operator has aligned the feeds)
- No Rain Fade analysis considered yet
- Minimal atmospheric losses

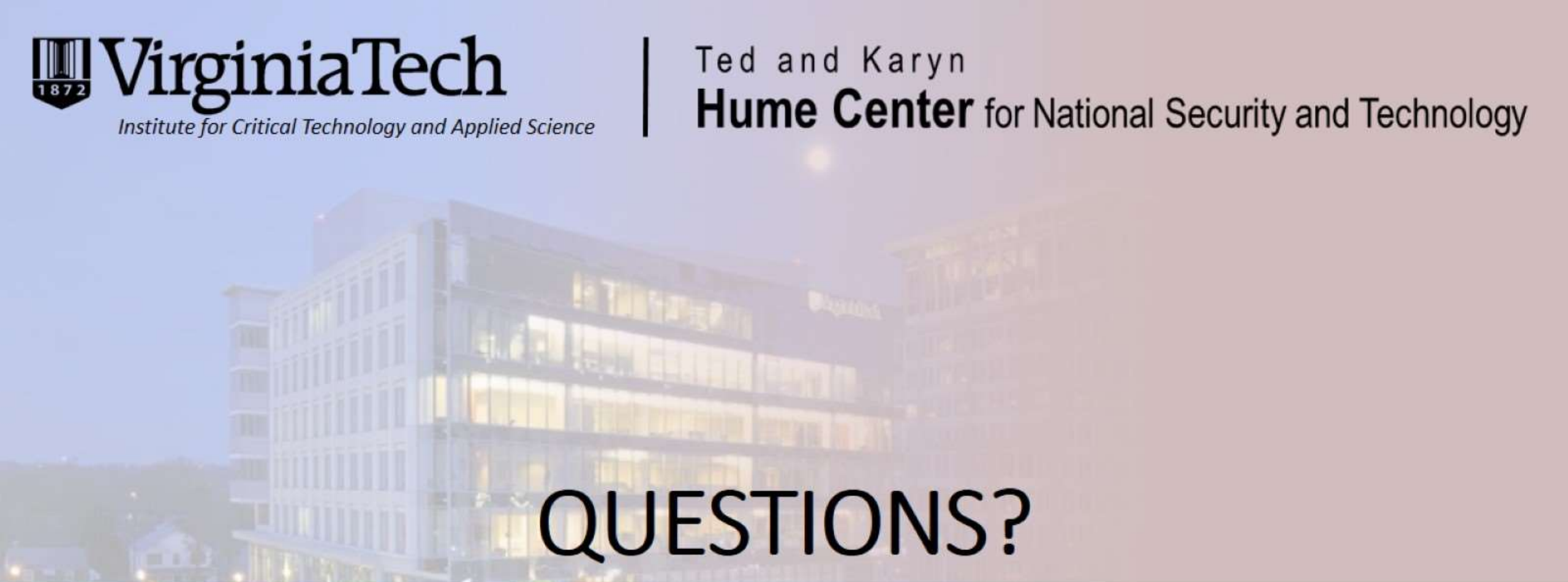


VirginiaTech

Institute for Critical Technology and Applied Science

Ted and Karyn

Hume Center for National Security and Technology



QUESTIONS?